

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

HEARING BEFORE THE SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT OF THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES ONE HUNDREDTH CONGRESS

SECOND SESSION

APRIL 27, 1988

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NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

WEDNESDAY, APRIL 27, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
RESEARCH AND ENVIRONMENT,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:40 a.m., in Room 2318, Rayburn House Office Building, Hon. James H. Scheuer [chairman of the subcommittee] presiding.

Staff Present: Michael Rodemeyer, Counsel; Wesley Warren, Republican Staff Consultant.

Mr. SCHEUER. The Subcommittee on Natural Resources, Agriculture Research and Environment will come to order.

The Subcommittee today examines the management of the National Acid Precipitation Assessment Program, hereinafter referred to this morning as NAPAP. The Subcommittee authorizes about \$65 million of the \$85 million currently funded, for interagency research through the research programs of the EPA, NOAA, the National Atmospheric and Oceanic Administration and the Department of Energy.

Now, since 1980, when the National Acid Precipitation Assessment Program, NAPAP, was created, we have spent over a third of a billion dollars studying acid rain. Yet, with only two years remaining in NAPAP's life, there are very serious questions out there as to whether NAPAP is fulfilling the mission for which it was created—namely to provide a scientifically credible, technologically sound, and technically sound assessment of the acid rain program that could be used by Congress and the President to make some tough, agonizingly complicated decisions on acid rain.

A review of recent events makes this hearing particularly timely. A year ago, the Government Accounting Office, the GAO, which is Congress' traditional investigating arm, released a report that can be only described as scathing, on the NAPAP program, which was then under the direction of Dr. Lawrence Kulp. The GAO found, among other things, that Dr. Kulp had failed to issue any of the reports required by law for the first 17 months of his tenure.

The 1985 assessment, which had been billed as the most significant document to date from the acid rain research program, was 2 year late, and key research areas were cut back, making it very unlikely that key information that was supposed to be provided to

Congress under the NAPAP plan, would be provided to Congress by 1990, which is the final report of NAPAP.

In September, 1987, NAPAP finally released its Interim Assessment to literally a firestorm of criticism. Critics charged that the 35 page Executive Summary authored by Dr. Kulp personally, distorted and misrepresented the findings contained in the voluminous research documents of several hundred pages attached to the summary. One week after the Interim Assessment was released, Dr. Kulp resigned.

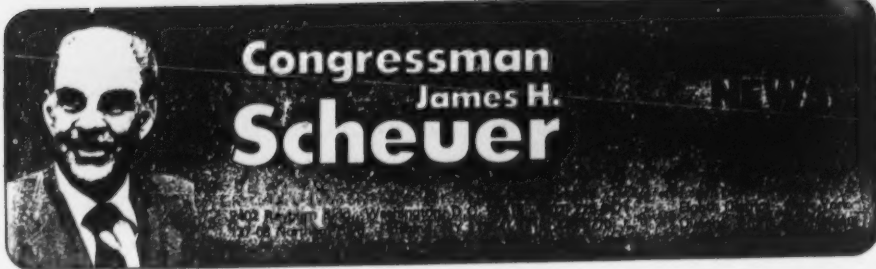
Today, the Subcommittee is pleased to welcome Dr. Kulp's successor, Dr. James Mahoney, who was appointed to the post only several weeks ago. Although he has served on the task force since 1982, and presumably is thoroughly familiar with all of the goings on which we will be discussing with him. We look forward to discussing with him and the members of the Interagency Scientific Committee who are accompanying him, several key issues.

We'll be discussing the findings of the Interim Assessment. We'll be discussing the plans for producing the final assessment due in 1990. We'll be discussing the scientific uncertainties which are likely to be unresolved by 1990, and we'll be discussing with him and his colleagues, plans for research after NAPAP's charter expires in 1990.

In the light of recent events, I'm particularly concerned about the conclusion of the General Accounting Office, that it's unclear whether NAPAP will be able to meet its goal of obtaining and analyzing research to be used as a basis for policy decisions by 1990. We want to know what we can realistically expect from the NAPAP program by 1990.

We've spent far too much money and far too much time for "we don't know," to be a viable or acceptable answer. We welcome the witnesses today and look forward to their testimony.

[The prepared opening statement of Hon. James H. Scheuer follows:]



OPENING STATEMENT
of HON. JAMES H. SCHEUER

Oversight of the National Acid
Precipitation Assessment Program

Hearings before the

Subcommittee on Natural Resources, Agriculture Research and Environment
of the

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

April 27, 1988

9:30 a.m. 2318 Rayburn HOB

The Subcommittee today examines the management of the National Acid Precipitation Assessment Program, or NAPAP. The Subcommittee authorizes about \$65 million of the \$85 million interagency effort, through the research programs of the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Department of Energy.

Since 1980, when NAPAP was created, we have spent over a third of a billion dollars studying acid rain. Yet, with only two years remaining in NAPAP's life, serious questions remain whether NAPAP is yet fulfilling the mission for which it was created: to provide a scientifically credible, technically sound assessment of the acid rain problem that can be used by Congress and the President to make policy decisions on acid rain.

A review of recent events makes this oversight hearing timely. One year ago, the Government Accounting Office released a scathing report on the NAPAP program, then under the direction of Dr. Laurence Kulp. GAO found, among other things, that: (1) Dr. Kulp had failed to issue any of the reports required by law for the first seventeen months of his tenure; (2) the 1985 Assessment, which had been billed as the most significant document to date from the acid rain research program, was two years late; and (3) key research areas had been cut back, making it unlikely that key information would be provided to Congress by 1990.

In September, 1987, NAPAP finally released its Interim Assessment to a storm of controversy. Critics charged that the 35-page Executive Summary authored by Dr. Kulp distorted and misrepresented the findings contained in the voluminous research documents attached to the Summary.

One week after the Interim Assessment was released, Dr. Kulp resigned.

Today, the Subcommittee is pleased to welcome Dr. Kulp's successor, Dr. James R. [redacted], who was appointed to the post only several weeks ago. We are looking forward to discussing with him, and the Members of the Interagency Scientific Committee who are accompanying him, several key issues: the findings of the Interim Assessment; the plans for producing the final Assessment due in 1990, the scientific uncertainties unlikely to be resolved by 1990, and plans for research after NAPAP's charter expires in 1990.

In light of recent events, I am particularly concerned about GAO's conclusions that "it is unclear whether NAPAP will be able to meet its goal of obtaining and analyzing research to be used as a basis for policy decisions [by 1990]."

We want to know what we can realistically expect the NAPAP program to produce by 1990. We have spent far too much money and waited far too long to take "we don't know" for an answer.

Mr. SCHEUER. May I recognize our ranking Minority Member, Claudine Schneider of Rhode Island.

Miss SCHNEIDER. Thank you, Mr. Chairman. The scheduling of this hearing has turned out to be quite fortuitous, seeing as how the President and the Prime Minister of Canada will be meeting today to discuss issues of mutual concern, including acid rain.

Two years ago, these two great leaders came together and they endorsed the conclusions of this report here, which was jointly prepared by special envoys from our two countries. And this study stated that acid rain is a serious environmental problem in both the United States and Canada.

Well, evidence continues to mount that this conclusion was correct and is correct. And this week, the Environmental Defense Fund released yet another report about the role of acid rain, and they linked environmental damage along the Atlantic coast, such as eutrophication and algae bloom, to acid rain.

Now, I think it's important to recognize that since the release of the special envoy's report two years ago, regrettably, this Administration has done little to indicate that it does, in fact, view acid rain as a very serious problem, and that it intends to correct this problem. Our most recent disappointment has been their handling of the Interim Report of the National Acid Precipitation Assessment Program—NAPAP as we affectionately refer to it.

The Executive Summary of this report is especially criticized for bending science into, and I quote, "non-action political agenda." These criticisms have been levied, not only by the outside witnesses that we're going to be hearing from this morning, but also by many of their eminent colleagues that work diligently in this field.

Once the NAPAP process is complete—in just two years, in 1990—the question that we will need to ask is, what have we gotten out of this? After 10 years and nearly half a billion dollars, the answer will be, we have gotten a lot of facts and very little action in controlling acid rain.

As we examine the future of this program, after 1990, we should seriously consider broadening its mission to include other pressing air quality issues. For example, last year in a report issued by EPA, which was entitled, *Unfinished Business*, it was very clearly stated that indoor air pollution was listed as a leading priority for this agency.

As we are encountering the prevalence of radon and other indoor air pollutants, I think that it is critical that we recognize that when we discuss the air, and we discuss unfinished business, this all has to be incorporated into a comprehensive priority action agenda.

I welcome the opportunity that this hearing provides us with, to weigh all of these issues, and I look forward to seeing the final NAPAP report, and working very closely with the Administration on future air quality needs, particularly insofar as our action agenda is concerned. Thank you, Mr. Chairman.

Mr. SCHEUER. Thank you very much, Congresswoman Schneider. Congressman Tim Valentine of North Carolina.

Mr. VALENTINE. Mr. Chairman, I thank you for recognizing me. I don't have any opening statement.

Mr. SCHEUER. Congressman Bob Smith of New Hampshire.

Mr. SMITH OF NEW HAMPSHIRE. Thank you, Mr. Chairman. Thank you also for holding this very timely hearing. I do ask unanimous consent to insert a statement in the record.

Mr. SCHEUER. There being no objection, so ordered.

Mr. SMITH OF NEW HAMPSHIRE. And just quickly, before starting, I would point out that I intend to be questioning perhaps as intensely as some of my colleagues on the NAPAP report. I think though, as we do this over the next hour or two, we all ought to keep in mind that, I think there's enough blame to go around as to why we don't have acid rain control legislation at this point.

Certainly the President, as we see in the front page of the Washington Post this morning, where the U.S. demands a higher limit on acid rain ingredient—I find this quite shocking and a little bit disgusting, quite frankly, that now in Geneva we're negotiating an international pollution agreement demanding a right for the United States to emit 20 percent more of nitrous oxide.

I don't understand how we can really look the Canadians in the face with this type of attitude, but apparently, we are able to do that.

But secondly, I want to point out—and finally, by the way—that there is plenty of blame to go around on this issue in the United States House of Representatives. Mr. Chairman, I'm not being political, because I've taken on my own President on it, publicly, privately for the last four years, but I also feel that the legislation must begin in the United States Congress. And we don't have it, and we all know whose doorstep falls on.

It falls on Senator Byrd in the Senate, and it falls on John Dingell in the House of Representatives. Let's call it where it is. We cannot get acid rain legislation out of this place without those two gentlemen, and we need them, and we need to have some people with influence in this Congress, to start moving to do just that.

And I would just finally say, from a personal standpoint, on the NOAA authorization bill, I included a couple of lines of an amendment which was passed unanimously by the House, which simply provided that acid rain pH content be reported or be sent to the weather stations—not that it be reported even, just that it be sent to them, and that authorization is being bottled up in the U.S. Senate by Senator Byrd, simply because of that language.

Now, I've been pressured to remove that language, and I'm not going to remove that language. And I think that what we've got to understand here, that this is not—although I am going to be critical of this NAPAP report, I am not going to stand for just simply having it be just the Reagan Administration, because the fault also lies with this Congress. Thank you, Mr. Chairman.

[The prepared statement of Hon. Robert Smith follows:]

--> FILE: HEARING .

STATEMENT OF REPRESENTATIVE ROBERT C. SMITH (N.H.-1)

APRIL 27, 1988

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND THE ENVIRONMENT
HEARING ON THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

THANK YOU MR. CHAIRMAN, AND GOOD MORNING. TODAY IS ACID RAIN DAY IN WASHINGTON, D.C. THE CANADIAN PRIME MINISTER, THE HONORABLE BRIAN MULRONEY, IS MEETING WITH THE PRESIDENT AND ACID RAIN CONTROL IS ON THE PRIME MINISTER'S AGENDA. THE CANADIAN GOVERNMENT HAS SET AN EXAMPLE FOR US OF FORTHRIGHTNESS AND RESPONSIBILITY ON THE ISSUE OF ACID RAIN CONTROL, A RECORD OF WHICH THEY SHOULD BE PROUD. I COMMEND THE CANADIAN'S FOR THEIR INITIATIVE AND FOR THE HIGH PRIORITY THEY PLACE ON PROMOTING ACID RAIN CONTROL IN THEIR INTERNATIONAL RELATIONS AGENDA.

SADLY FOR THE ENVIRONMENT AND FOR ALL OF US, WE HAVE YET TO GET AN ACID RAIN CONTROL BILL PAST COMMITTEE IN THE U.S. HOUSE OF REPRESENTATIVES. OUR OWN GOVERNMENT SPONSORED RESEARCH EFFORT, ON WHICH AMERICAN TAXPAYERS HAVE SPENT \$389 MILLION DOLLARS, IS NOW IN ITS EIGHTH YEAR. TODAY WE WILL CRITICALLY EXAMINE THE PROGRAM TO-DATE, AS WELL AS SET THE STAGE FOR THE FINAL REPORT FROM THIS GROUP TWO YEARS FROM NOW WHEN NAPAP EXPIRES.

THE INTERIM ASSESSMENT REPORT THAT WAS PUBLISHED LAST FALL AFTER TWO YEARS OF DELAY WAS NAPAP'S FIRST ATTEMPT TO SYNTHESIZE THE CURRENT STATE OF KNOWLEDGE ON ACID RAIN. AS YOU RECALL, MR. CHAIRMAN, I REQUESTED THIS HEARING BECAUSE, WHILE THE QUALITY OF THE NAPAP RESEARCH CONTAINED IN THE THREE SUPPORTING VOLUMES WAS WELL RECEIVED, SINCE THE DAY THE INTERIM ASSESSMENT FINALLY BECAME PUBLIC, THE INTERPRETATIONS CONTAINED IN THE EXECUTIVE SUMMARY DOCUMENT HAVE MET WITH RIGOROUS CRITICISM FROM THE SCIENTIFIC COMMUNITY. IN FACT, A WEEK AFTER ITS RELEASE, THE AUTHOR OF THE EXECUTIVE SUMMARY, DR. KULP, RESIGNED FROM THE NAPAP PROGRAM.

CONTROVERSY REMAINS OVER WHETHER THE DATA ARE PRESENTED IN A WAY THAT UNDERESTIMATES THE NUMBER OF ACIDIC OR SENSITIVE LAKES AND, IN GENERAL, THE DEGREE OF THE ACID RAIN PROBLEM. FOR EXAMPLE, THE NAPAP EXECUTIVE SUMMARY IGNORES SMALLER LAKES, BIOLOGICAL EFFECTS, AND THE ALKALINITY OF LAKES, WHICH IS THEIR ABILITY TO NEUTRALIZE ACID. IN ADDITION, THE REPORT SELECTIVELY USES A PH OF 5.0 AS A CUTOFF POINT FOR DEFINING AN ACIDIC LAKE, INSTEAD OF A PH LEVEL THAT IS MORE REPRESENTATIVE OF LEVELS WHERE DAMAGE TO AQUATIC BIOTA OCCUR.

THE EXECUTIVE SUMMARY MAKES ASSUMPTIONS RELATIVE TO FUTURE ENERGY SUPPLIES THAT ARE UNREALISTIC. OF NOTE HERE, THE EXECUTIVE SUMMARY ASSUMES THAT POWER PLANTS CONSTRUCTED PRIOR TO PASSAGE OF THE CLEAN AIR ACT WILL BE RETIRED BY THE BEGINNING OF THE NEXT CENTURY AND ASSUMES THAT NUCLEAR POWER USE WILL TRIPLE OVER THE NEXT 40 YEARS. WITH RESPECT TO THE FORMER, UTILITIES ARE EXTENDING THE LIVES OF PRE-CLEAR AIR ACT POWER PLANTS WITHOUT IMPLEMENTING POLLUTION CONTROLS. AS TO THE LATTER, NO NEW NUCLEAR POWER PLANTS HAVE BEEN ORDERED IN OVER A DECADE.

WHILE THE INTERIM REPORT CLAIMED TO BE A STATE OF THE SCIENCE REPORT, DR. G.E. LIKENS, DIRECTOR OF THE INSTITUTE OF ECOSYSTEM STUDIES, OBSERVES THAT THE EXECUTIVE SUMMARY MUST EITHER IGNORE OR DISMISS THE THOUSANDS OF ARTICLES PUBLISHED IN HIGH QUALITY JOURNALS THAT SHOW SERIOUS ECOLOGICAL DAMAGE CAUSED BY AIR POLLUTION AND ACID DEPOSITION. EXTENSIVE WORK DONE BY THE CANADIANS WAS IGNORED BY DR. KULP AS WELL.

IT IS CLEAR THAT WE WILL NOT HAVE ALL THE ANSWERS ON ACID RAIN BY 1990. HOWEVER, THAT IS NO REASON TO IGNORE EARLY WARNING SIGNALS OF AN IMPENDING ENVIRONMENTAL EMERGENCY. IT IS SAFE TO ASK, I BELIEVE, WHETHER COMPLETE KNOWLEDGE OF ACID RAIN WAS EVER OUR GOAL IN AUTHORIZING THE NAPAP STUDY. THE PURSUIT OF SCIENCE, BY ITS VERY NATURE, IS A PROCESS OF DISCOVERY WHICH SERVES TO GENERATE A CONTINUOUS STREAM OF NEW QUESTIONS. CONGRESS INTENDED

THAT THE NAPAP STUDY IMPROVE OUR UNDERSTANDING OF THE DYNAMICS OF THIS PHENOMENON, ASSESS THE STATE OF THE RESOURCES AFFECTED BY IT, AND PRESENT A SERIES OF RECOMMENDATIONS TO CONGRESS.

I THINK THE COMMITTEE SHOULD MAKE IT CLEAR IN THIS HEARING, TWO YEARS IN ADVANCE, THAT IT INTENDS FOR THE FINAL NAPAP REPORT TO BE COMPLETED ON TIME. WE HAVE THE OPPORTUNITY TODAY TO PROVIDE INPUT ON THE FINAL DOCUMENT, TO ENSURE THAT THE NEXT NAPAP EXECUTIVE SUMMARY IS AN OBJECTIVE PRESENTATION OF THE STATE OF THE SCIENCE.

IN REGARD TO THE FUTURE OF NAPAP, IN MY OPINION WE HAVE AMPLE EVIDENCE THAT DAMAGE IS OCCURRING AND THAT A REDUCTION IN SOX AND NOX WOULD LESSEN DAMAGE CAUSED BY THESE PRECURSORS OF AIR POLLUTION AND ACID RAIN. SPENDING MORE TIME AND MONEY TRYING TO DISSECT WHICH POLLUTANT IS SPECIFICALLY RESPONSIBLE FOR OBSERVED DAMAGE MAY, FROM A FEASIBILITY STANDPOINT, BE AN EXERCISE IN FUTILITY. IN THIS HEARING I LOOK FORWARD TO EXAMINING WHAT THE CONTINUED AREAS OF UNCERTAINTY ARE IN ACID RAIN RESEARCH, AS WELL AS TO FUTURE DISCUSSIONS WE WILL HAVE IN CONGRESS ON WHETHER OR NOT TO REAUTHORIZE THE PROGRAM FOR SPECIFIC AREAS.

BECAUSE FOR THE MOST PART, PEOPLE HAVE READ ONLY THE INTERIM ASSESSMENT'S EXECUTIVE SUMMARY DOCUMENT, THE EPISODE LAST FALL WAS DAMAGING FOR THE FEDERAL ENVIRONMENTAL RESEARCH COMMUNITY. THE FINE WORK DONE BY NAPAP'S SCIENTISTS HAS BEEN OVERSHADOWED BY PUBLIC DISTRUST FOR THE FEDERAL RESEARCH EFFORT CREATED BY DR. KULP'S TENURE. THE NAPAP PROGRAM ADMINISTRATOR'S TASK AHEAD IS TO REGAIN CREDIBILITY WITH THE PUBLIC, CONGRESS, AND THE SCIENTIFIC COMMUNITY.

Mr. SCHEUER. Well, you could have quoted Shakespeare to us this morning, Congressman. The fault, dear Brutus, lies not in the stars, but in ourselves. And you're absolutely right. You hit the nail on the head. It's unfortunate that we have two Committee Chairmen in the House and the Senate who come from Michigan and West Virginia, two of the most polluting states in the nation—Michigan generating cars and West Virginia generating soft coal.

And that is a real problem, and it has had a crippling and disabling effect on Congress' meeting the challenge of facing up to acid rain in an adequate fashion. And combined with the Administration's do-nothing attitude, and their attitude that we should engage in research for the sake of research as a substitution for action, we are in the present pitiful condition of doing nothing in the face of mounting evidence that we ought to be doing something.

I couldn't agree with my colleague more, and as far as our relations with our Canadian friends are concerned, we ought to be embarrassed to look them in the face. I remember President Reagan's first official act in terms of foreign affairs, was to greet the Prime Minister of Canada, in January or February of 1981. And he promised at that time, he committed himself at that time, that we were going to do something about acid rain. And the performance of the President, and the performance of the Congress, as you say, have been equally pitiful and shameful in the ensuing years.

I'd like to yield to my colleague, Tim Valentine—excuse me, Tom McMillen of Maryland.

Mr. McMILLEN. Mr. Chairman, I just want to say briefly that I commend you for holding these timely hearings to take a closer look at the process of eutrophication which has a major effect on the Chesapeake bay, an estuary that is of vital importance not only to my district in the state of Maryland, but to our country at large. And I'm looking forward to these hearings with great anticipation. Thank you.

Mr. SCHEUER. My colleague, few states have as critical a problem of acid rain as does the state of Maryland, and few states have as active and knowledgeable and effective members concerned about this problem as Maryland.

Congressman George Hochbrueckner of my state of New York.

Mr. HOCHBRUECKNER. Thank you, Mr. Chairman. I also would like to commend you for holding these hearings, and I would like to say from my own prospective, coming from an engineering background, that I think there are great opportunities in the area of clean coal technology which can help solve the problem, and at the same time, meet the political concerns that obviously have affected the inaction that has occurred by Congress. Thank you, Mr. Chairman.

Mr. SCHEUER. We'll now ask Dr. James Mahoney and his colleagues from the National Acid Precipitation Assessment Program to come to the witness table. I believe Dr. Mahoney will be accompanied by members of the NAPAP Interagency Science Committee; Dr. George Jordy, from the Department of Energy; Dr. Charles Philpot, Department of Agriculture; Dr. Jack Pickering, Department of the Interior; Dr. Courtney Riordan, EPA; Dr. Lester Machta, NOAA; and Dr. James Morris, the Tennessee Valley Au-

thority. If you'd all come forward and join us at the witness table, we'll commence the hearing.

Gentlemen, we are very happy to have you here this morning. This should be an interesting hearing. You have heard something of the concerns of the members of this subcommittee, Dr. Mahoney. I hope you will address them in the course of your testimony.

Why don't you take 10 or 12 minutes or such time as you may need. You are the key witness here this morning. Tell us about the history of NAPAP, where we are, where we are headed, and perhaps addressing some of the concerns that you have heard here in the last half-hour. Please proceed.

Miss SCHNEIDER. Mr. Chairman, before our first witness begins, let me apologize and say that I have a markup before my other committee on the Alaska National Wildlife Area, so I will have to duck out. I thank you for bringing together such an illustrious series of witnesses, and I will try to be back later in the morning.

Mr. SCHEUER. Very good.

Miss SCHNEIDER. Thank you.

Mr. SCHEUER. We will try and accommodate you on your questioning.

Dr. Mahoney, please proceed.

STATEMENT OF DR. JAMES R. MAHONEY, DIRECTOR, NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM, ACCOMPANIED BY MEMBERS OF THE NAPAP INTERAGENCY SCIENCE COMMITTEE: DR. GEORGE Y. JORDY, DEPARTMENT OF ENERGY; DR. WILLIAM SOMMERS, DEPARTMENT OF AGRICULTURE; DR. R. JACK PICKERING, DEPARTMENT OF INTERIOR; DR. COURTNEY RIORDAN, ENVIRONMENTAL PROTECTION AGENCY; DR. LESTER MACHTA, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION; DR. JAMES S. MORRIS, TENNESSEE VALLEY AUTHORITY.

Dr. MAHONEY. Thank you, Mr. Chairman.

As I start, I would like to mention that we have one substitution of name. Dr. William Sommers is here instead of Dr. Philpot representing the Department of Agriculture, and I would like to have that noted for the record.

Also, Mr. Chairman, as I begin I would like to respond to Miss Schneider by pointing out I would be most pleased to answer questions in or outside the context of this hearing if it happens you are not able to be back, and I look forward to the chance.

Mr. SCHEUER. We will hold the minutes open for written questions if Congresswoman Schneider or any of my colleagues wish to submit them, and we will give you ten days or two weeks to answer them, but when Madam Schneider comes back, we will give her a chance to ask her questions out of turn. Please proceed.

Dr. MAHONEY. Very good.

I want to thank you indeed very much for your invitation to appear here before the subcommittee today and to review the status and the plans for NAPAP. I undertook the position of Director of NAPAP on March 1st, and since that time I have attempted to review the entire program, noting the many scientific accomplishments of the program as well as the many concerns which

have been expressed and which you have summarized, in fact, in your opening statement this morning.

Based upon my review, I would like to begin my testimony by outlining the two points of general strategy which we are developing to make the most effective use of the scientific information and the technological information developed by NAPAP.

The first of these two points: A high quality program of research has been and is being conducted by NAPAP. By 1990 we will have a much greater base of information to assist in decision-making about acid deposition than we do now, and, I might say, even more than we did a few years ago. Our first point of strategy, therefore, is that we will continue careful management and scientific peer review of the research activities under way. We will make changes in emphasis and direction as necessary, but we will keep the overall research program on its current course.

Second in my two points of strategy: The organization and the reporting of the technical information developed for assessment purposes needs extensive development and structuring to allow full use of the research findings. Several changes in our assessment methodology are already under way, including greater involvement in structuring the questions to be addressed by the user community.

We intend to involve all of those who would use the information in the process of defining what it is specifically we will address and how we will address it. When we view that user community for this assessment, our list includes at the minimum you-all in the Congress and your staff, the various Federal and State agencies, the various agencies at the provincial and national government level in Canada, and other foreign agencies, all of the environmental groups, the industry groups, and the scientific community itself, which has a stake in seeing good science done for good public purpose in this case.

We aim to provide a very useful integrated assessment in 1990, and I might note that the planned deadline for submission is 2-1/2 years from now. Our deadline is September 30, 1990. Moreover, we aim to make the process, the interdisciplinary process we are now conducting a beneficial model for consideration for dealing with other issues which combine these traits of complex technical analysis and important public policy decisions, such as the broad range of questions we see in the geosphere-biosphere interaction area.

In the rest of my statement, Mr. Chairman, I want to respond to the questions you posed in your opening statement and in your invitation to me. First I want to speak for a moment about the interim assessment document, which you have already discussed. Each of the technical chapters in the interim assessment was reviewed by several external scientific specialists and totaled more than—

Mr. SCHEUER. Excuse me. What was reviewed by the external specialists?

Dr. MAHONEY. Each of the technical chapters, Mr. Chairman, in the interim assessment.

Mr. SCHEUER. You understand that our main complaints don't go to the scientific validity and objectivity and professionalism of the several hundred pages of reports. What our concerns run to is the

quality of and the methodology involved in the 35-page executive summary.

Dr. MAHONEY. Mr. Chairman, yes, I do indeed, and I intend to speak about that. I would note also, though, that there have been many scientific comments raised about the material in the technical chapters. That is in the normal course of doing good science, of course, too. The entire purpose for writing down information is so that those who would want to review it can challenge and discuss. So I was speaking first about the technical chapters and the matter that there is a desired dialogue to be carried out about the technical matters. And then, of course, we need to address your specific concern about the executive summary.

Mr. SCHEUER. Excellent.

Dr. MAHONEY. To finish the comment on the technical material first, we plan to invite those scientists who have provided critique and, in most cases, written critique on the technical material in the documents. We plan to invite these individuals to meetings with the NAPAP staff and with key NAPAP-affiliated scientists so that we can do something which is responsive to our charter as you provided in the original statute: that is, to carry out scientific inquiry and carefully examine those scientific questions.

As to the executive summary, we recognize that the critiques of the summary have focused on issues of emphasis and issues of definition and those issues which you have described in your opening statement. We are carefully considering these critiques in developing our plans for the 1990 assessment, and we will publish for public comment and review and revision later this year a detailed plan for that final assessment, which will include definitions of all of the significant effects being considered under the name of acid rain and explicit questions about those effects and their scope and the means of control to be addressed in that document.

We will have this available in a few months this year. We will then conduct a national public hearing so that we will have a formal mechanism for receiving written and verbal comments about the entire scope of our plan to define and structure the information that we have to present to the nation in this area, and we will revise, then, that plan to reflect those comments.

We intend to have this updated plan for the 1990 assessment through this process of publication, receipt of review comments and revision by later this year so that there will be approximately two years remaining for the NAPAP scientific and technological resources to be directed toward answering those questions which we have agreed best define and characterize the problem we are dealing with.

Going on with my statement, the next question you raised in the invitation to testify was that about management changes, and in particular, I presume, the matter that I now occupy the position of director. I want to point out, as you noted in your opening statement, that I was an appointee of the president to the Oversight Task Force for NAPAP beginning from 1982. As a result, I have had an opportunity to see NAPAP's operation and structure over all the time between then and the current time.

I have to note with reserve that the scope of NAPAP's activities and technical studies is so broad that an appointee external over-

sight reviewer is not able to deal with that material in great detail, or at least I could not. So I have to be careful to note that I am not in a position to speak with expert view about all of the work carried out in the last five years.

Mr. SCHEUER. Dr. Mahoney, I take it you can speak with some authority about the content and the adequacy of the 35-page executive summary.

Dr. MAHONEY. I would hope I could, Mr. Chairman, yes.

Mr. SCHEUER. Very good.

Dr. MAHONEY. Bringing it to the current time and my role as director of the program, I note that the challenge for any new incumbent would be substantial even if he has had earlier contact with the program. For example, the process of achieving adequate scientific perspective about all of NAPAP's activities, which include nearly 300 projects under way right now, would take many months, at the least.

Mr. SCHEUER. Dr. Mahoney, there is a roll call vote going on now and we are going to have to suspend for about 15 minutes to get that. We can go on for another minute or two before that or we can do that now. Which would you prefer?

Dr. MAHONEY. If you would like, Mr. Chairman, in one minute I could conclude my matter on my view of my own role, and then we can come back to specific plans going forward, if you would like.

Mr. SCHEUER. Excellent.

Dr. MAHONEY. I would simply conclude the comment about my own role coming into the position of director by noting that my own technical experience over many years has been emphasizing the interaction between technical research and public issues and their resolution. So I bring this frame of reference to my view of the position, and I wanted to recommend that my goal for NAPAP's 1990 assessment is that when it is released, that it be viewed as credible by both its users, all of those I mentioned before, as well as by the scientific community which should validate that the work represented is sound.

[Brief recess.]

Mr. SCHEUER. The Committee will continue. Dr. Mahoney, you still have some of your affirmative testimony to finish up. Please proceed.

Dr. MAHONEY. Thank you, Mr. Chairman. I'll try to proceed and finish this to get on to your question phase promptly.

I do want to move next to respond to your question about our plans for preparing the 1990 assessment. We have adopted a series of guidelines for that assessment and I'd like to simply state those for the Subcommittee at this time.

The guidelines are these. The 1990 assessment must first be based on credible scientific information which is available to all of the users of the assessment. It all must be carefully documented.

Second, and probably most importantly for the sense of your hearing, the assessment must be developed from a structured plan which includes a careful definition of all of the effects of acid rain studied, and include specific questions to be addressed and resolved in the assessment.

This plan must be reviewed by all of the identified user groups interested in the assessment, and the plan must be open to modifi-

cation to include consideration of the comments and suggestions made by those user groups.

And I might divert from the statement just a moment on this key point to make it clear that we view that the assessment process is something that goes beyond the underlying science.

We all understand that the role of the scientist is to do his studies, or her studies, develop information, present it, have it carefully reviewed, identify uncertainties, and make it available to any reader or user.

In the assessment process, we are challenging our scientific community to structure their information in this very complicated matter, to put the parts together and to lay down a plan about how it will be put together in a way that all of those who want to draw conclusions from this, you all in the Congress in particularly obviously, can see our best effort to so structure it.

And we believe you need to see that this year and we need to work to the plan that you and others interested have seen and commented upon, and then we have adopted with adequate revisions later this year.

Going on to the other points in our guidelines for the integrated assessment, it must document all of the data used finally in drawing conclusions.

It must show the quality assurance methods adopted. And remember, with field measurements the matter of careful quality assurance is always important, else we can give the problem away by poor measurement right at the beginning.

And we must also document all of the computer models used so that we don't have the models substituting for our judgment through some error or misunderstanding which is not apparent to the subsequent user of the information.

And we must document all of the uncertainties associated with the assessment process. Beginning from these guidelines we have adopted a series of specific plans and, indeed, I have given most of my first two months on the job to this matter of the process so that we can get this started, and then we can go back and look at our science in some more detail.

But I have had the chance to carry the recommendations for plans I will now present to the joint Chairs responsible for the program, and have gotten their approval on the matters I will now describe to you as our specific operating plans for the next two and a half years.

First of all, our reports in 1990, I might add parenthetically that I don't mean we should disappear and not report anything until 1990, but our final reports when the time comes will include two separate but very closely related series of documents.

One half of that series will be a careful survey of state of science and state of technology that relate to the acid rain question.

The other half of the series will be specifically the integrated assessment with our findings and the best recommendations we can make.

Both of these series of documents will be prepared by the same team of scientists and engineers to assure that the underlying information conforms to our best view of the science.

Obviously, we don't want one group to prepare something and another group to take it away and draw conclusions from it.

The integrated assessment summarizing a structured set of findings and recommendations will be based on the information which we carefully document in the state of science and state of technology reports, and that assessment will be structured around questions which evaluate the extent and the severity of acid deposition effects, together with our best views of the means to reduce or mitigate these effects.

Next, this state of science summary information will be developed in the form of approximately 20 very high quality survey papers written for the first line specialist audience to give our scientists in the program a chance to take every part of the program and lay out in the best way our views of what we know and what we don't know.

And I might note that separating this state of science summary in a sense a half step from the assessment, makes sure that our scientists can tell us what they know and can draw conclusions in the best scientific sense, citing uncertainties and the like, without feeling that they have to look over their shoulder about whether what their saying for that purpose is somehow a recommendation about what we should control.

We feel that to respond to your mandate, we need to carefully say, as I say, what we know, what we don't know and the like, we'll get that stated and then in parallel with that we will carefully structure those statements into a common view of findings and recommendations relative to the problem.

Mr. SCHEUER. Dr. Mahoney, I'm reluctant to interrupt you, but I just want to clarify in my own mind what you've been saying for the last minute or two.

Do I understand you to say that this collection of outside experts that you're bringing in, and some members of your inter-agency scientific committee, are going to give us a cost and benefit appraisal of what the existing science tells us.

The cost of controls and the benefits in terms of remediation of the problems of acid rain on forests, lakes, streams, structures and so forth.

Am I correct in assuming you're going to address yourselves to costs of remediation and benefits from remediation?

Dr. MAHONEY. Mr. Chairman, the answer to your question is, yes, we will indeed. I may have misled a little bit in the way I described the role of the scientists, so—

Mr. SCHEUER. Well, that's why I wanted to clarify that. I don't want to be misled and I know you have absolutely no intention of misleading us.

And I respect the bona fides with which you're approaching this testimony. We're very appreciative of that. And I just wanted to clarify that for the record, that we are going to hear something in the next, well, in the remainder of this year that we didn't find in the Executive Summary.

Namely, an appraisal of costs and an appraisal of benefits so that we in the Congress and the Administration can bite the bullet and make some tough public policy decisions that we have to make based on your best efforts at giving us costs and benefits.

Dr. MAHONEY. Yes, Mr. Chairman, let me respond with a—

Mr. SCHEUER. I take it that's your intention.

Dr. MAHONEY. Yes, it is, indeed.

Mr. SCHEUER. Well, we're very much encouraged by that.

Dr. MAHONEY. I want to be careful, though, so I don't mislead or over-promise as to the timing of the delivery of that information.

Mr. SCHEUER. All right. Tell us something about timing. When do you expect to come up here with it?

Dr. MAHONEY. What I'm describing as a process is a — we have first the step that we will prepare, we are in fact already started now on preparing a plan for this assessment.

And as I will come to it to give a few specifics simply from the statement in a moment, the plan does include directly consideration of costs and benefits.

And that plan will be published, it's our hope, within, say, three months. I don't want to give that as a promise yet because it may well be four months or more before we can get through all the complexities involved.

That plan for the assessment will not, by itself, have dollar estimates in it, but it will indicate how we are preparing those.

Mr. SCHEUER. You'll have that, conservatively speaking, by Labor Day, or shortly after Labor Day?

Dr. MAHONEY. I think that's a good characterization, yes. Yes, sir.

Mr. SCHEUER. And if you don't have the figures on costs of remediation and figures on the benefits of remediation, you'll give us some idea of the process by which you plan to achieve those figures, and the system, and some timetable, I presume, for when they will be available.

Dr. MAHONEY. Yes, sir. We will, specifically, and we have in mind the formal comments in the GAO report, which you referenced in your opening statement.

We know the requirement of the statute and the reminder in the GAO report that this be covered. To be clear, I note that it is inappropriate to develop economic analyses when the uncertainties are so great that the problem is not well scoped.

Now, we could argue about whether they should have appeared last year, but standing today, our view is, number one, we have to respond to the mandate to provide this information; and, number two, I believe that we have the information to make a reasonable estimate and that, in fact, what NAPAP should be doing, obviously we don't do the value analysis finally, but our job is to structure information including costs and benefits, make it available so that it can be viewed and debated and argued about, and then you all and others who have to review the process, can have this at least as a starting point as the best estimates we can provide you.

Mr. SCHEUER. Well, Dr. Mahoney, you had me back on my heels for a minute, or maybe I should say on the edge of my chair for a minute, a few paragraphs back.

But as you proceeded, you answered all our questions and we'll be very satisfied and very encouraged if you do just what you said you were going to do in the last few sentences.

I apologize for interrupting, but your testimony has been very interesting, very thoughtful, very provocative, and in many ways encouraging. Please continue.

Dr. MAHONEY. Thank you, Mr. Chairman, and I'll try to finish promptly so you can get on to broader questions.

Mr. SCHEUER. There's no rush. Take your time, Dr. Mahoney.

Dr. MAHONEY. Okay, thank you. I would say next, at the time we stopped for this very useful dialogue to clarify this important matter, I was about to describe in some more substance the elements of the plan for the assessment which we expect to publish for your review and for the public's review later this year.

These are listed, I would note for anyone making a reference on Page 9 and 10 of the prepared statement. Our plan for assessment will include the following items.

There are ten of them altogether. First, the specific definitions of the effects being considered to our best ability to say, what precisely do we describe as the effects, the range of them, that have to be considered.

Second, the questions we need to put about this. No one in the room will dispute the matter that is acid rain bad for us? Yes, it is. The matter is a much more specific and formal set of questions about what we can do.

Third, the means by which we characterize the severity of effects. How do we characterize a problem in lakes or other surface waters and forests and the like.

We have many definitions and much dispute about this, but one of the principal things NAPAP can do is to help propose definitions we could come to some agreement about which give us a common base for examining these effects.

Next, the methods and databases available to prepare geographic and other inventories of these effects. It's one thing to know we're concerned about what goes on in an individual lake.

It's another thing to say, how many lakes like this might we have in North America, and we have to define exactly how we try to do that.

Mr. SCHEUER. That was one of the things that concerned us very much about the Executive Summary. They talked about acres, but they didn't talk about number of lakes. And your addressing the number of lakes would be a big help to us.

Dr. MAHONEY. Thank you. I would point out there were statements about percentages of lakes and the data on numbers there, but that point by itself might argumentatively be a difference in style as to presentation.

But I know the sense of your overall concern. Simply, to finish the list then, our plan for our final products will also include the approaches we use in demonstrating cause and effect relationships.

And we all, whether we are proponents or concerned observers of possible control, have to deal specifically with what do we know, is our view of causation direct enough to assure that if we invest the national resources in control finally, that we'll get some real benefit from it.

And, again, NAPAP, of course, doesn't deal with what we should invest finally, but we should do our best job of telling you what the

science says about our degree of knowledge and certainty in that cause and effect chain.

Mr. SCHEUER. This point that—we are very appreciative of your attitude and your stated intentions and what you've just told us is, of course, essential to the work when you pass the ball us and to the Administration.

And let me assure you that there is nobody on this Subcommittee, or this full Committee, or in this Congress, that wants to impose any silly, unproductive, unjustifiable costs on business, on commerce, on our economy.

We are in a desperate state of competition in trying to retain our role as world class actors in global commerce. Nobody wants to burden industry with foolish, silly, unjustifiable costs. That's the last thing we want to do.

What we're looking for is a level of control that is clearly sensible, that is clearly justifiable, practical, doable, and that will not impede industry in any significant extent in competing abroad.

We know that industry is in a desperate state of needing to compete, and not with one arm tied behind their back. So, let me just reassure you and the Administration that we are all as one here and this crosses party lines in the House, it crosses bicameral lines, it goes to the House and the Senate, both parties, we want to do what's clearly sensible, what's clearly justified.

The point of view of the Administration up to now in the last eight years is that we have to know everything to do anything.

We don't believe that anymore. And most scientists don't believe it. They think there is a certain minimal level of control procedures and processes that we can direct take place, that is clearly justifiable.

We're not looking toward a 100 percent pollution free environment. We're looking for work-a-day, hands-on practical results that are viable and that are economically justifiable. So, we are as one in that hope and that intention. Please proceed.

Dr. MAHONEY. Thank you, Mr. Chairman, indeed. Completing my list of those elements in the plan for the assessment, we will be addressing, again, the matter of the emissions data for the common pollutants and their future projections.

We will provide an updated view of the state of control measures, various technologies, various alternative practices, which might bring us to lower emissions.

Because the engineering and scientific job is to survey all the most efficient, least costly means of achieving what you decide we have to achieve, finally.

And, as you asked before, you'll find written here specifically, we will be providing economic analysis methods. And, I might comment just a moment on the matter that there are two halves to the economic analysis problem.

One is on the control half and the other is on the effect, or benefit, half. On the control half, I certainly wouldn't claim to speak for economists with whom I've been speaking frequently now, there are many disputes about how you might approach control cost estimation, keeping in mind all the matters of annualizing capital costs and energy penalties and dis-efficiencies and the like, but at least that part of the problem is rather concrete.

And we can do it and debate the results, and I would argue the range of uncertainty is not too great. I say that to focus us for just a minute on the benefits side.

We know for policy evaluation that we would like to have the best view possible of a dollar estimate for all of the related effects and their mitigation that we're dealing with, the lakes and forests and so forth.

In some areas, if we're talking about commercial productivity for commercial forests, for example, we can give those dollar estimates.

When we deal with basically non-monetary matters, preservation of our environment over the long time, we can make attempts to use the various economic assessment methods available, and we will do this because it's important to make an estimate.

But I simply warn while viewing this that no one should ever assume that it is as simple as saying, here is \$50 billion of costs and here are \$80 billion of benefit as defined by some method like this, and we know what we should do.

So, in presenting that, as NAPAP, we will do our best job of providing information of this sort, and through the means of this hearing, though I call attention to the fact that our information must be used well.

We'll try to do our job, but we have to be certain that it doesn't take it out of context and quote it in a way which isn't intended as we develop it.

In that sense, we will be presenting our plans for full economic assessment that will accompany the final, the 1990, reports and will be developed in the time between now and then.

Now, I'd like to close this part quickly so I'll move on and note you also asked in your invitation for my views about the scientific and policy uncertainties which will remain in 1990.

I'd start by noting that we have seen the evolution of substantial changes in our scientific views about acid rain over the last many years.

Now, I don't mean that anyone would now say we don't have a problem as compared to a few years ago, but I would note that, in the late 1970's and early 1980's, most of the focus on acid rain was rather specifically on the control of sulfur oxides.

And strategies, had they been developed or imposed at that time, would have addressed that issue alone, I would argue, or would have most likely done that because that was really our focus.

In more recent times, we have seen the great importance of ozone as a damage agent for the forests and in other cases.

When we view control strategy, clearly we have to view those things together in making the choices about how to achieve the most benefit for any controls finally imposed.

And even more recently, we have seen a good deal of information about atmospheric chemistry processes which suggest changes in our knowledge about the scope and geographic coverage of acid deposition associated with various patterns of emission.

Taking this all together to your question of what we'll know in 1990, I view that the assessment methodology and framework we are now developing, and will publish for your review, we hope will represent a constructive step toward putting all of this information

together while leaving the door open to the new things we'll hear, but at least giving a structure so that we'll have something much more of the nature of a common base to work from.

With all that in mind, I would draw the attention of the Committee to one broad area of uncertainty that I feel will remain in 1990.

We'll do our best before then, some of this is outside of the scope of NAPAP as now constructed, but it is this view that regional air pollution problem is, I think nearly all observers would now say, is very much viewed as a combined oxidant and acid problem.

The controls for oxidants are, in large part, different than those for the acid species. They're the same in the case of nitrogen controls, but they're different otherwise.

I'm certain that no matter what we do in the next two years, we will have substantial questions about the combined impacts of oxidants and the acid species to address in 1990 and beyond.

But I note it now because clearly we should pay as much attention from this time as we can in the context of our analyses.

Finally, you have asked about research needs and program structure which might go on beyond 1990. In the matter of research needs, I am not now prepared to give a detailed list, which ought to command a good deal of thought and, indeed, would be most appropriate after we have been through this assessment planning that we are now doing over the next few months, but I can certainly cite the general categories of the research needs that will go beyond 1990.

First on the list is continued trend monitoring. It is essential that we do not back away from supporting the programs of field measurement that will give us in the end our best ground truth on whether we are making progress or not in the next several years. So in my view, any forward-looking view has to start with the essential need to keep that kind of base program under way.

Second, we will need to keep the data bases and computer models that are used for the various analyses current so that we don't invest all that we have in this program and find in one year that no one knows how to run the models or has kept the data base up to speed.

Third, there will be many special studies that will need to continue, some of which are already identified by the agencies and are, in fact, long-term studies. You can't do a ten-year growth profile for forests in three years no matter what we set for a program, as an obvious example.

Fourth as a category, we have much to do to continue our work on dose response functions, dose response analyses. That is right at the heart of the question. If we are going to have deposition in our waterways or forests, we know that there are responses, that some are important and some are not. We have to continue, in our view, to better understand these so that we can support the investments for control that may need to be made.

I will close with a comment on future program structure. To do a good management job, we entirely intend to present the NAPAP final reports on deadline in 1990, and we are prepared to do all we can to give interim reports of real substance as we go along. I would be glad to work with the committee and committee staff and other committees, in fact, to let you know the details of our pro-

grams and try to respond to special questions as we can, consistent with doing good quality scientific work along the way. But we will end the program and deliver our reports as required.

Obviously, the needs for analysis in this area will not go away at that time, and indeed, when NAPAP finishes and delivers its results of the decade of work, we believe that a major benefit of it is the set of information and analysis that will be put on the table for use by the Congress and others subsequently to make some of these difficult analyses.

So I have suggested in my statement and I would say here as a kind of a closing point, given that we know there is a need but that there are substantial questions about the level of investment in NAPAP and the utility of an interagency program, I have tried to capture it in one sentence this way: If the benefits of this kind of integrated assessment are adequately demonstrated by the plan we now develop and its working out over the next two years, and if policy-relevant questions still remain two years from now, then I believe we should carefully examine or you-all and the Executive Branch should carefully examine those means which would capture the good aspects of this program for continued use.

It may well not be all aspects because we know there are things that could be done better, but I think we should leave it on the table for considering what would be, in my view or jargon, a post-NAPAP program, perhaps, not an extension of NAPAP but the issue of let's take what we have seen and learned, and where we have remaining issues, let's consider the model and improve it and put the appropriate elements of some follow-on program into place.

Mr. Chairman, thank you for entertaining a long statement. I hope this has been useful in giving you a view of the plans we are developing.

[The prepared statement of Dr. James R. Mahoney follows:]

STATEMENT OF JAMES R. MAHONEY
DIRECTOR OF THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM
BEFORE THE SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
RESEARCH, AND ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

APRIL 27, 1988

Thank you for your invitation to appear before the Subcommittee today, to review the status and plans for the National Acid Precipitation Assessment Program (NAPAP). As you requested, I am accompanied by members of NAPAP's Interagency Scientific Committee.

Since I undertook the position of NAPAP Director on March 1, I have reviewed the status of all major aspects of the program, noting the many program accomplishments as well as the several concerns about the Interim Assessment which have been expressed during recent months. Based on this review, I wish to begin my testimony by outlining the two-part strategy we are developing to assure effective use of the major research activities carried out by NAPAP.

First, a high quality program of research, field observation and computer model development is being conducted by NAPAP. Because of the program's design, by 1990 we will have a much greater base of information to assist decisionmaking about acid deposition management requirements, compared to the information currently available. Continued careful management and scientific peer review of these research activities will be maintained; changes in emphasis and coverage will be adopted as needed, but the overall research program direction will be kept on its current course.

Second, the organization and reporting of technical information for assessment purposes needs extensive development to allow full use of the research findings, analysis methods and data bases developed by NAPAP. Several changes in assessment methodology are already underway, including greater involvement by the user community (Congress, Federal and state agencies, Canadian and other foreign agencies, environmental and industry groups, and the scientific community) in the assessment planning process. I will summarize these later in this statement.

With continued emphasis on high quality, well-reviewed scientific studies, combined with a carefully structured, publicly reviewed assessment plan, we aim to provide a very useful Integrated Assessment in 1990, responsive to the requirements of the 1980 statute. Moreover, we aim to make the NAPAP interdisciplinary process a beneficial model for consideration in dealing with other issues which combine complex technical analyses with important public policy considerations, such as the many questions of biosphere/geosphere interactions.

In the remainder of my statement, I will respond to the questions posed in your invitation.

NAPAP's Interim Assessment. The Interim Assessment, released in September 1987, was developed jointly by all of the technical task groups involved with the program. Each of the technical chapters was reviewed by several external scientific reviewers selected to reflect the diverse

technical issues covered in the chapter. In total, over 50 technical reviewers, representing the university sector, industry, state, federal, Canadian and other foreign organizations, participated in this review process. In each case, the reviewer comments were specifically considered by the chapter authors. In addition to this external review process, each chapter was extensively reviewed by scientists in the various federal agencies responsible for the NAPAP work.

Several technical critiques of the Interim Assessment have been received, and these are all being considered currently. Moreover, I plan to invite those scientists who have provided written comments on the Interim Assessment to discussion meetings, which will also include the appropriate NAPAP-affiliated scientists, to provide for a good dialogue on technical issues. This is the best means to assure that the final NAPAP report will have the benefit of the full range of scientific analyses of the available data.

The critiques of the Interim Assessment's Executive Summary have focused on issues of emphasis and definition. We are carefully considering these critiques in developing our plans for preparing the 1990 Integrated Assessment. We will publish for public comment, later this year, a detailed plan for the Final Assessment, which will include definitions for all significant effects and explicit questions to be addressed in the Assessment. We will encourage full review of this plan by all expected users of the Assessment, and others with an interest in the acid deposition issue. We will consider the review comments in developing the final plan, and the key definitions and questions to be addressed. This process will be limited only by the resources available for analysis and the constraints of good scientific practice.

Impact of Recent Management Changes

I have served as a Presidential Appointee on NAPAP's Interagency Task Force from 1982 until taking the position as Director last month. This has provided me with the opportunity to evaluate the structure, functions and principal findings of NAPAP since the time of its early operations. I have not had the time available to function as a detailed reviewer of NAPAP's reports over the years. However, I have carefully observed its scientific peer review processes, and I find that they have provided extensive and good technical advice, and have documented high-quality analysis in many of NAPAP's program elements.

Because of my familiarity of NAPAP's activities for more than five years, I have been able to avoid some of the learning curve delays which often occur with a change in management. However, in at least two aspects, the challenges for a new incumbent in the principal management position are significant. First, the scope and coverage of NAPAP's sponsored studies are so broad that significant time is required to place them all in perspective, especially because the studies must all be properly integrated in the 1990 Assessment. Second, scientific analyses must be evaluated critically and not simply summarized. The process of achieving adequate scientific perspective on all of NAPAP's nearly 300 currently sponsored projects (combined with the information available from its completed projects) will continue during the next several months.

While there is always some loss in short-term efficiency associated with senior management changes in a large scale activity, I trust this will be offset by the new perspectives introduced. My technical experience and special interests include an emphasis on the effective use of multiple discipline scientific information as background for public policy evaluations. This emphasis has special importance during the final reporting phase of NAPAP's activities. My goal for NAPAP's 1990 Integrated Assessment is that it be viewed as credible by both the scientific community and the user community.

Plans for the 1990 Integrated Assessment

Since taking up my new position, I have given greatest priority to planning for the 1990 Integrated Assessment. A specific plan for the Assessment is needed at the earliest possible time, because the requirements for the 1990 reports influence virtually every aspect of current NAPAP activities. In beginning to formulate the Assessment plan, I have met with the Interagency Task Force members, the Task Group Leaders, many of the principal investigators, the Interagency Scientific Committee, the Interagency Policy Committee and many non-NAPAP scientists. The Assessment plans will continue to be developed over the next months, and will be published for comment later this year. The NAPAP Joint Chairs Council has approved the following guidelines and operational plans regarding the 1990 NAPAP reports.

Guidelines for the 1990 Integrated Assessment

The 1990 Integrated Assessment must:

1. Be based on credible scientific information which is available to all users of the assessment.
2. Be developed according to a structured plan, which includes (a) definitions of all effects studied, and (b) specific questions to be addressed. The plan must be reviewed by all identified user groups, and modified to include consideration of the user comments.
3. Document all data, quality assurance, methods, computational analysis methods, and computer software used, to facilitate subsequent analyses by user groups.
4. Define uncertainties, to allow users to evaluate confidence in reported findings.
5. Be structured to facilitate incorporation of new information (e.g. continued trend monitoring data, new dose-response models, improved emissions estimates.)

Specific Plans for the 1990 Reports

Consistent with the guidelines, the Joint Chairs Council has approved the following specific plans to assure that credible and useful products are obtained from NAPAP's activities during the final 30 months of the program:

1. The 1990 products will include two separate but closely related series of reports: (a) state-of-science and state-of-technology (SOS/SOT) surveys and (b) the Integrated Assessment. These will be prepared by the same team of scientists and engineers, to assure that the assessment information directly conforms to the underlying science and technology information. The SOS/SOT reports will address the broad state of our knowledge including the cause and effect mechanisms related to acidic deposition, and the control measures available to reduce the effects. These will draw upon the entire body of reviewed technical information (i.e., they will not be limited to NAPAP-sponsored studies).

The Integrated Assessment will be based on the information reported in the SOS/SOT documents, and will be structured around questions that evaluate the extent and severity of acidic deposition effects, and the utility of various strategies to reduce these effects. The Integrated Assessment will document the technical

analysis methods available to analyze control strategy options, and will illustrate the methods with applications to a limited number of representative control and mitigation strategies. The data and evaluation methodologies will be available to all interested users (e.g., Congress, federal and state agencies, Canadian and other foreign agencies, environmental and industry groups, and the scientific community) to investigate specific strategies as they may desire. Thus, NAPAP will develop and document evaluation methods using a limited number of scenarios for illustration, will discuss factors leading to uncertainty in the results, and will provide a common technical resource for other specific evaluations by user groups.

2. The SOS/SOT information will be developed in the form of 20 or more high quality technical survey papers, each of the scope and quality appropriate for an invited paper in a specialist publication. Complete manuscripts for the papers will be required by summer 1989.
3. NAPAP will sponsor an international technical specialty conference, to be held in the United States in late 1989, to review these papers. The conference will include (a) presentation of the survey papers by their authors, (b) presentation of critical review comments on

the survey papers by invited reviewers (who will receive the manuscripts two months in advance of the meeting), and (c) contributed papers, to allow updated reports on new data as appropriate.

4. Completion of the SOS/SOT papers by summer 1989 will provide the documentation of the technical information for the 1990 Integrated Assessment.
5. The SOS/SOT papers will be updated in 1990, to account for information developed during the international technical meeting, and to incorporate new results of ongoing technical studies by NAPAP and other programs. In order to achieve a defined endpoint for the NAPAP work, the final 1990 versions of the SOS/SOT papers will be published (after full peer review) in a single major document summarizing the technical information developed during the NAPAP process.
6. A detailed plan for the 1990 Integrated Assessment is currently under development. Last week a group of 75 NAPAP-affiliated scientists, engineers and economists met to initiate the final assessment planning process. The assessment plan will identify (a) specific definitions of effects being considered, (b) the questions to be addressed by the assessment, (c) the methods to characterize severity of effects, (d) the

methods and data bases available to prepare geographic and other inventories of effects, (e) the approaches used in demonstrating cause-effect relationships, (f) planned sensitivity analyses for the effects evaluations, (g) the emissions data base development and projection models, (h) the control technologies being evaluated, (i) data bases, analysis methods and computer models to be used to characterize atmospheric transport, transformation and deposition, and (j) economic analysis methods and non-monetary approaches to benefit evaluation. After review by the Task Force and Joint Chairs Council, this plan will be released for public review and comment later in 1988. An open meeting will be scheduled to receive written and verbal comments on the plan, and a revised plan will be prepared after consideration of the comments. The revised plan, to be available in late 1988, will guide the development of the Integrated Assessment to be completed in 1990.

7. An overall scientific committee will be appointed by the Joint Chairs Council to review the assessment plans and NAPAP's technical performance during its final reporting phase. Periodic reviews by this committee will be sought throughout the remaining life of the program, until the 1990 Integrated Assessment is complete.

Scientific and Policy Uncertainties Likely to Remain in 1990

Various scientific reports of long range transport of pollutants, with deposition by wet and dry processes, appeared during the 1960's, and significant field research was undertaken in Europe during the 1970's. However, information developed as recently as the past few years has significantly changed our perspective about dose-response mechanisms and atmospheric chemistry processes important in determining the geographic extent and magnitude of acidic deposition. For example, we now recognize the potential importance of ozone effects on trees, and available evidence suggests very little acidic deposition impact on crops in the United States. Also, the importance of atmospheric oxidant species, especially hydrogen peroxide, in the formation of acid aerosols has been identified only recently.

I anticipate that we will have a much improved base of information for examining the need for and effectiveness of various control strategies for acidic deposition by 1990, for the following broad reasons:

1. Knowledge of dose-response mechanisms for acid deposition alone, ozone alone, and combined ozone-acid deposition impacts is developing rapidly. Depending on the importance of these different mechanisms, different decisions could be made.

2. Knowledge of regional atmospheric chemistry has developed rapidly in the past few years, and is now incorporated in major computer models for the first time. When these models are adequately evaluated (using field measurements scheduled to begin in June 1988), they will provide a much improved ability to evaluate the effectiveness of emission controls in reducing regional deposition levels.
3. The Integrated Assessment methodology being developed by NAPAP will provide a well documented framework for public dialogue on evaluation of options for addressing the acid deposition issue.

The NAPAP Interim Assessment report, at pages I-6 and I-7, summarizes the uncertainties substantially reduced by 1987, those expected to be reduced by 1990, and those expected to remain after 1990. That summary is, in my view, still entirely accurate. However, I note for the Subcommittee one major uncertainty not previously reported (because it was not within the scope of the Interim Assessment): the regional air pollution issue is increasingly being viewed as a combined oxidant/acidic species system, and more extensive combined information on sources, atmospheric processes, and effects will be needed.

Research Needs and Program Structure After 1990

NAPAP is scheduled to terminate its program activities by the end of 1990, and all of its reports are scheduled for publication by that time. Several technical activities will be critically important in the post-1990 time frame when individual agency activities will continue independent of the NAPAP structure. It is not appropriate to prioritize individual research needs until the detailed 1990 assessment plan is completed. This planning process will allow identification of key research gaps relevant to the needs of policy formulation. As a preliminary statement these research gaps will include the following categories:

1. Continued trend monitoring for air quality and deposition rates at non-urban sites, as well as ecosystem monitoring, such as forest health and aquatic chemistry.
2. Maintenance of data bases and computer models developed as part of NAPAP, to assure their continued utility for policy analysis.
3. Special studies of many types, especially those dealing with combined stresses (multiple pollutants and other stresses) in ecological systems.
4. Continued dose-response studies, some of which require many years for response evaluation.

On the question of post-1990 structure, NAPAP has been a useful example of both the advantages and disadvantages of a long term, interagency research and assessment effort directed to an important public issue. The regional air quality problem will not be resolved by 1990, and regional air quality cause and effect studies will be required well beyond 1990. I am not prepared to recommend a specific post-1990 structure at this time. However, (1) the need for carefully coordinated long-term assessment activity is clear, and (2) we expect to demonstrate the benefits of the Integrated Assessment approach within the next twelve months. Therefore I respond to your question about post-1990 program structure with a challenge to the NAPAP group: If the benefits of an Integrated Assessment program are adequately demonstrated by the assessment plan and state-of-science surveys developed within the next year, and if policy relevant uncertainties are expected to remain after 1990, then consideration should be given to a post-1990 program for continued assessment of combined species regional air quality management.

Before closing, I want to note the significant advances already achieved by the NAPAP program in promoting interdisciplinary research efforts, and the advances in the understanding of basic ecosystem and atmospheric processes which will contribute substantially to the body of knowledge necessary to assess future global scale problems.

Thank you again for your invitation to review the NAPAP activities and plans with you today.

Mr. SCHEUER. Thank you, Dr. Mahoney. Your statement has been useful and in many ways gives us ground for hope that things are going to improve and that we are going to get a degree of integration which we haven't seen up to now, which is very important, and in general that you are going to be responsive to this drum beat of criticism you heard not only from the Hill but from scientific circles at all points in the spectrum.

I would now like to yield to my colleague from North Carolina, Tim Valentine.

Mr. VALENTINE. Thank you, Mr. Chairman.

I want to say at the beginning that I think that I recognize a parochial political interest as well as any member of this body, and I think that while some members of the Congress are guided primarily by those considerations on this question of acid rain, that for most members, this problem would not come within their catalogue of interest that were nearest and dearest to their hearts.

But I have experienced a certain amount of frustration in an attempt to make a determination as to what the Congress should do when confronted by people and interests who would really prefer that we do nothing—who say to us, well, nobody really knows, congressman, what we should do; that this body of scientific opinion says that the destruction which occurs to the great national forests in the southeastern part of the United States and other woodlands is not because of the problem that some other people say that it is; that we don't know what to do, so you shouldn't support this legislation because it might be harmful, indeed.

Do you think that what you are about, that the National Acid Precipitation Assessment Program will really produce some answers to some suggested solutions, or will it, in your opinion, come forward with an opinion and several dissenting opinions?

Dr. MAHONEY. Mr. Valentine, we have discussed the view of entertaining reports of dissenting opinions directly in the various reports that NAPAP would issue over these next two years in the sense of providing a full range of viewpoints where that is appropriate. However, the mission of NAPAP is to integrate and structure our overall information to do the best job we can of identifying a series of priorities so that you and your colleagues in the Congress, as well as, we might say, the nation generally, can view those and either agree or change them in your own mind, but ultimately decide which of the many effects that we are investigating are those that deserve controls to what level.

So we do see the concept as that of integration and structuring, and to do that job, we have to create the lists of those effects we believe are important and carefully document them, which was what I was trying to indicate in the statement, and understand that that material, we hope, would be used in the sense of good inquiry intended. Not as a whipping boy. Anyone can dispute the list, but someone has to take responsibility to say what are the most important ones and how severe are they and what should we really control.

Our view is that that is what the Congress has charged NAPAP to do in this program. The science has gone on a long time and is continuing very intensely right now, but in this reporting phase, we have got to pull that information together and give you the best

fruits of our scientific view in a way that allows you to help make the differentiations you spoke of.

Mr. VALENTINE. Is there an organization similar to this in existence and operating in Canada? Similar to NAPAP.

Dr. MAHONEY. Similar, but I would not argue it is exactly the same. But yes, sir, similar skills and focus are available.

Mr. VALENTINE. The chairman of our committee, of course, has been a leader in the effort to do something about this problem since I have known him, and you can just feel the frustration when he talks about the situation confronting our Canadian neighbors, and I understand that. We talk about the 1 to 10 ratio in the population in this colossus to the south of Canada, ten times what they have, but when you put into focus the fact that, as I understand it, a substantial and maybe as much as 75 percent of Canadian industrial development would be within 100 miles of the Canadian-U.S. border, and the potential for a problem from industrial pollutants there, what I want to know is are you able to tell us, Doctor, what has Canada done?

A lot of talk has been heard here about our obligation, and I have had people come to me through the back door and say, well, Congressman, you guys ought to do something; but they haven't really done a lot in Canada except ask us for action. What do you say to that?

Dr. MAHONEY. Mr. Valentine, let me answer to the best of my knowledge. I am not prepared to give a broad, expert view about the Canadian actions. Specifically, I have had so much on my plate in the last two months since assuming this job, I have not stepped aside to examine the Canadian side directly. Even so, the Canadians use proportionately less electric power generated from fossil fuel combustion than we do here on our side of the border because of the large amount of hydropower available given the small population base.

Second, as to reducing sulfur dioxides, a major fraction of all of the sulfur dioxide emission in eastern Canada has arisen from a few large smelter operations, including, in particular, the one in Sudbury, as is well known. The Canadians have taken substantial steps to reduce the emissions from those individual facilities.

Canadians are also now embarked on a program to control motor vehicle emissions to bring them down to the range we have already controlled here in the United States, so the Canadians are doing things and it makes it easy to cite rhetorical statements on either side. I would argue in some cases, though, the Canadian emissions per capita and per industry type and per vehicle are coming down more nearly toward the U.S. emissions.

The problem is, as you first stated, the United States population base is so much larger that we are the net exporter. No one disputes that the net flow across the border of the pollutants is from the United States toward Canada, and that arises in the end because of the very large population on our side of the border and the related industry and so forth.

Mr. VALENTINE. Thank you, sir.

Thank you, Mr. Chairman.

Mr. SCHEUER. Congressman Bob Smith.

Mr. SMITH OF NEW HAMPSHIRE. Thank you, Mr. Chairman.

I, too, Dr. Mahoney, want to thank you for your candor and realize that you stepped into a very difficult position. I don't want to dwell on the past, but in reviewing the difference between the interim report and the executive summary, I think it is a fair question to ask could you give to the Congress some explanation—I mean we have an oversight responsibility here in this ten-year study, if you will, and can you give us some explanation as to why the striking difference between the executive summary of Dr. Kulp and the interim assessment? What is the motive for the difference? Was it Kulp himself? Just what is the reason for such a stark difference between the two items?

Dr. MAHONEY. Mr. Smith, I would want to be very careful about trying to speak about motive because that is so inferential and I don't know directly, as a short and honest answer to that. But I would like to, if I could, go back to the first part of your question and cite that I have tried to look very closely, of course, at the interim assessment and the related documents. All that you asked me, of course, is a series of obvious questions for me coming into my position.

I honestly believe that the interim assessment and the executive summary is not as distant from the underlying science as it is often characterized as. What I think I see, and I tried to use the words in my statement, is a difference in emphasis, a difference in issues covered. It is hard to find something in the executive summary that you could call inaccurate based on what is in the document.

What I see is that that executive summary was released in a—this is all a highly contentious matter. It was disputed quickly on every side, and as a simple tactical matter or a matter of procedure, the fact that it had not been seen or viewed in draft in a formal sense meant that it was a target for characterization as being widely different from the underlying reports, and I don't think it is that widely different, is my comment.

Mr. SMITH OF NEW HAMPSHIRE. We don't have time to go into the whole document. Obviously, I don't have time, and in my line of questioning, I have so many questions I don't know where to begin, really, but I disagree with your assessment there. I think that, just to use a couple of examples, the emphasis on not including smaller lakes, for example, in the summary. I forget the acreage size, eight or nine acres or whatever it was. That is number one. Number two, using a different acidity pH for the yardstick.

I think this NAPAP summation cut right into the credibility of the whole ten-year study. It certainly did with me. It has got the Canadians furious. I am sure that is on the table today with Prime Minister Mulroney and President Reagan. I think it has hurt badly this report, the whole study, the credibility of the ten-year study.

By the time this thing is completed, you are looking at approximately \$500 million in expenses. We could have put a hell of a lot of acid rain controls on, just converting to low sulfur coal. Let's forget the control. Let's just convert to low sulfur coal. We could have done a lot of conversions for 500 million bucks and had something to look at at the end of ten years that we could put our teeth into.

So I guess what I am asking you is this thing has been overstudied and under-resolved, let's face it, the whole issue. You can find

scientists on both sides. You know that and I know that. I guess what I am asking you is, at the end of the ten years or in 1990 when you come in with your final report, which I hope will be on time, Mr. Chairman, are we going to see just another ambivalent study that does not get definitive, that does not come to the point and say yes or no, we need implementation legislation, we need controls or we don't? Are we just going to have another one of these ambiguous reports that doesn't say anything that costs us a half-million dollars?

I am tired of it. I am not a scientist. I can't sit here like you gentlemen and say whether or not all of the acidity in the lakes or all the problems that we have related to acid rain are caused, necessarily, by coal-burning power plants. Of course that is not the case. But the point is that if we had some controls and we phased them in—and some of us in Congress have been trying to do that with legislation, not dramatic legislation, just a start like the Canadians have done. I think the Canadians have shown that there has been an effect on what they have done. I think they have proven that. I don't think there is any question about that even by the doubters.

So I guess I am asking you a big question here, but what are you going to conclude in the end? Are we going to have a definitive statement about acid rain at the end of this ten-year study?

Dr. MAHONEY. I believe we will have as definitive a statement—I hate to have to use any extra words. I would like to say simply: "Yes, sir." In fact, Mr. Smith, we have to understand the complexity and the uncertainty of the whole problem, so there is no way that the scientific or the engineering community can simply say yes and no about choices that the Congress will have to make. But I don't mean that to be an apology or a leaving the door open.

I would like to represent that what I tried to outline in my written statement and to summarize here in my comments represents our very best thought and, as an individual, my very best thought to the matter of structuring all of our information so we can do all we can on exactly that. We intend, as I say, to publish this plan in the next few months as soon as we can get it viewed and reviewed properly.

We are trying to say that we understand there are a whole range of effects of acid rain. What we want to do is to try to once and for all give our best view of how severe and important these various effects are, how widespread they are, and how much we know about what specifically the sources are, what specifically causes one set versus another set, and give that information to the Congress and the nation in a form that can greatly advance the ability to take from that and make some decisions.

Mr. SMITH OF NEW HAMPSHIRE. We've spent, I think the figure is \$389 million, that we've spent so far in research thus far, and at the Federal level, that we've spent.

You know, it just seems to me we have enough research to be able to conclude. At least there is some cause/effect situation.

But there are so many inconsistencies. I didn't say, you did state that Dr. Kulp's summation was not inaccurate. I didn't say it was inaccurate, but I think it was misleading.

I think you can play the games with statistics if you use a pH of 5 instead of a pH of 6, if you use small lakes instead of large—or if you don't use small lakes, you use large lakes.

But there are a lot of inconsistencies in terms of both congressional and administrative policy. For example, the Clean Air Act. I mean, you mentioned the ozone, the fact that ozone and acidity are both factors.

They are. Well, then, we ought to pass the Clean Air Act. We haven't done that, we haven't reauthorized it. And I think that a combination of implementation legislation and the Clean Air Act might give us some yardstick to measure this thing by.

And, yet, we don't do either. If, again, I'm going to repeat myself, Mr. Chairman, but if we go back at the end of 1990 and we get another ten year study, millions of dollars more spent on research, probably somebody will want to reauthorize the thing for another ten years, NAPAP for another ten years, will spend another billion dollars to study it some more.

And I just think we ought to once and for all just get down—you ought to have the guts to come forth and say, look, it's not a problem, it'll go away, we'll go to solar power ten years from now and the hell with it, it'll go away, don't worry about; or, it is a problem, and we ought to do something about it.

I think it's time we do that. But some of the statistics, I don't mean—it's not your fault, you're the new guy and I don't mean to direct it at you, but some of the statistics in there and the facts in that summation are ludicrous.

For example, as the Chairman knows and this Committee knows, we just changed a policy regarding a second nuclear waste repository. We totally eliminated it to go to one repository because of a 40 to 50 percent expected reduction in nuclear waste because we're not building nuclear power plants any more.

And for them to conclude in there that we're going to have three times as many nuclear power plants and, therefore, that is, in the next 20 years, by the year 2030 rather, the next 50 years, that's going to be a factor in causing us to have less of a problem with this, is absolutely ridiculous.

And that's coming from the same government, the same Department of Energy with two conflicting analyses, and it doesn't make any sense.

I'd like somebody to answer that question. How can you say that by the year 2030, we're going to have three times as many nuclear power plants, and at the same time, come out and say that the DOE would come forth and say, well, we don't need a second repository because we're going to have 50 percent reduction in nuclear waste.

If you've got a power plant, you've got waste, unless somebody has come up with a way to take care of that. I'd like somebody from DOE to answer that. And that's my final question, Mr. Chairman.

Mr. JORDY. This is one of the questions that was raised in the Canadian—

Mr. SCHEUER. If the gentleman could make this a brief answer, we're going to have to—the second bells are coming in a minute or

two and we have about two minutes after that, and then we're going to have to break.

Mr. JORDY. The projections that were used in the modeling were based on the fifth national energy plan, and that plan did foresee a reemergence of nuclear options after the turn of the century.

Now, we're working on the sixth, and that's not available at this time. If it's assumed that nuclear generation does not increase above the projected level for 2000, in other words you have a cap at 2000, SO₂ emissions would be about 1.5 million metric tons higher in the year 2030 than projected in the base case.

So, if you add 1.5 million metric tons to what you saw in the base case, for the year 2030, that would correct for the forecast in continuing growth of nuclear power.

In other words, that would mean increase of about eight percent over the 2030 forecast of the total SO₂ emissions, but would still represent a decrease of 10 percent from the 1980 level.

Mr. SMITH OF NEW HAMPSHIRE. So, you're suggesting we wait until 2045 before we have any implementation legislation?

Mr. JORDY. No. I'm not suggesting that at all.

Mr. SMITH OF NEW HAMPSHIRE. Well, you're projecting out there, so I just—

Mr. JORDY. I'm telling you what would happen if you corrected the NEPP5 for nuclear growth. Putting a cap on it in 2000 would increase SO₂ emissions in 2030 by 1.5 million tons. That's eight percent higher than what you saw in the report.

Mr. SMITH OF NEW HAMPSHIRE. Thank you, Mr. Chairman.

Mr. SCHEUER. We'll suspend for 15 minutes for this roll call vote. [Brief recess.]

Mr. SCHEUER. We will start in again. When, as and if Congressman Hefley returns, I will yield to him as I indicated I would.

Dr. Mahoney, we have found your testimony very interesting and we have found you to be a thoughtful and forthright witness, and we appreciate that. That, we hope, is a harbinger of change. Let me ask you just a few questions, not to take up too much time.

As several of us have indicated, the National Lake Water Survey was a large survey that at best could provide an accurate snapshot of the condition of a large number of lakes at one point in time. The survey did not involve long-term studies to determine changes in pH over the seasons, and as you know, the pH factor is generally higher in the fall than it is in the spring. It didn't go over a number of years to observe acid rain deposition levels.

Yet the executive summary states, and I quote, "Most lakes in the Northeast are unlikely to become more acid in the near future." Now, do you find factual verification for that in the several hundred pages of documentation that undergirded the executive summary? In other words, is this a statement of fact or is this a possibly interesting hypothesis?

Dr. MAHONEY. I believe that is a statement of inference from the underlying information. I don't think any statement can be called simply that of fact.

Mr. SCHEUER. Is it a logical inference that you would deduce from looking at all of the evidence on an integrated basis? Would that be a logical inference?

Dr. MAHONEY. I believe it can be, but—

Mr. SCHEUER. No, no, no. I don't want to know if it can be. I want to know if you consider that to be a logical inference. They made a finding that to many of us is in absolute, stark conflict with the clearly understood, credible evidence of these hundreds of pages of scientific documentation. They say most lakes in the Northeast are unlikely to become more acid in the near future. Now, as best I understand the Queen's English, that is a simple, declarative sentence. Do you agree with it?

Dr. MAHONEY. I believe the statement deserves further investigation.

Mr. SCHEUER. Dr. Mahoney, this 35-page executive summary was supposed to be an integrated analysis of two or three hundred pages of scientific documentation. Now, if we have to take a simple, declarative statement of fact out of that 35-page statement and say it deserves further scientific investigation, doesn't that give you pause as to whether this 35-page executive summary really is an executive summary?

Dr. MAHONEY. Sir, yes. Can I consult with my colleagues for a moment?

Mr. SCHEUER. No, no, no. You don't need to consult with your colleagues.

Dr. MAHONEY. Mr. Chairman, the reason that I answer with some hesitation, as you—

Mr. SCHEUER. With great hesitation.

Dr. MAHONEY. Well, for good reason.

Mr. SCHEUER. Of course you have good reason. I wouldn't want to be sitting in your seat right now. That is a very embarrassing question, and you are in the catbird seat and you have to answer it. Would you like me to move to the next question?

Dr. MAHONEY. No, sir. I would like, if I could—

Mr. SCHEUER. Do you subscribe to that one sentence? That is a simple, declarative sentence as I understand the Queen's English, and after all, the Queen's English is the one thing that separates us from the beasts of the jungle, the ability to convey thought clearly and concisely. Do you subscribe to that statement?

Dr. MAHONEY. I will suspend and not subscribe to that statement at this time.

Mr. SCHEUER. Thank you very much. Now let's go on to the next question. You are a very honorable man. Can I ask you: Isn't it true that a panel of scientists reviewing EPA work stated that it is presently impossible to state how many more lakes are likely to become acid in the near future?

Dr. MAHONEY. Yes, sir.

Mr. SCHEUER. They have said that. Okay. Isn't it true that even if the lakes have reached, as a hypothesis, a steady state, a chemical steady state, that at the same time, further biological damage could be occurring?

Dr. MAHONEY. Yes, sir, I think that is true, and I don't think the statement would argue against that, the summary.

Mr. SCHEUER. All right. Now, the interim assessment used Canadian data. One hundred fifty thousand lakes up there have been damaged. Why wasn't the Canadian data on aquatic damage included in the assessment? Wouldn't it be relevant for U.S. policy-makers like me and my colleagues and the Executive Branch to

know of the damage that we are inflicting on our good neighbor to the north, our number one trading partner and a country with whom we have had 3000 miles of ungarded, unarmed borders for the entire history of this republic?

Could the data have been omitted because the resources at risk in Canada, their forests, their grazing lands, their croplands, their rivers their streams, could it have been that those resources in Canada that were at risk absolutely dwarf those that are at risk in the United States? Could that be a reason why it was omitted?

Dr. MAHONEY. Mr. Chairman, the data were omitted because of serious questions about the scientific comparability of the Canadian data set compared to that available on the United States side. We have a plan to go back to our colleagues in Canada and address the issues of data comparability so that we can include full consideration of that data, taking account of real scientific questions about interpretation in the work we are doing at this time.

Mr. SCHEUER. Can you just tell me briefly, because time is running short, what was the problem in comparability?

Dr. MAHONEY. As I understand it—and I want to explain, because it reflects on me, not on the report otherwise, that—

Mr. SCHEUER. Wait a minute. Dr. Mahoney, let me make it very clear none of this reflects on you. You are the new boy on the block. You came on deck after this report had been issued. Nobody holds you responsible for it. This was a personal achievement of Dr. Kulp's. He must have gone into the attic and written this 35-page report on his own because there was no peer review, there was no involvement of the Interagency Scientific Committee, as Congress certainly expected would happen. This was an individual creation of Dr. Kulp, and he quit within days after it was released. So nobody is holding you responsible.

What we would like to hold you responsible for is taking proper, thoughtful, prudent and scientifically justified efforts at remediating some of the damage. I am not talking about damage that is done by acid rain; I am talking about damage that is done by this very confusing, very mischievous, very destructive 35-page summary.

So please, I want to make the record very clear that nobody is holding you responsible for anything, and we think you have the potential and the possibility of doing an exemplary job, based on many of the things you have said this morning.

Dr. MAHONEY. Thank you, Mr. Chairman.

Mr. SCHEUER. Let me ask you another question. The executive summary contains a projection of future sulfur dioxide emissions that contains a number of interesting assumptions, some of which have been pointed out by my colleague from New Hampshire, Congressman Bob Smith.

The assumption that current generating plants will be retired after 50 years flies in the face of all hands-on practical experience. That nuclear generation will treble by the year 2030 when we are virtually out of the business of producing nuclear facilities.

That new clean coal technology will be rapidly adopted. I don't know where the evidence for that is. You can find it in Japan. There isn't a single energy producer in Japan that doesn't have scrubbers. At the Sudbury plant in Canada not many miles north

of the border, formerly one of the biggest polluters in the world, are spending millions and millions of dollars correcting that, putting on the state of the art technology. Across the length and breadth of industrial Europe—leaving aside Great Britain, who is stalling and hulking down, just as we are—the European countries are rapidly installing state of the art anti-pollution devices. We are not.

It seems to me that to make these three assumptions that the Congressional Research Service called over-optimistic and improbable really is disingenuous. You might call it the 1988 new definition of chudzpah, really, to present that kind of conclusionary thinking to the Congress and to the Executive Branch. It boggles the mind.

Dr. MAHONEY. Mr. Chairman, with respect, could I respond on one matter on this?

Mr. SCHEUER. Of course. Yes, indeed.

Dr. MAHONEY. Because I am not in a position to respond as fully as I would like, speaking as an individual. This was the sense of my—

Mr. SCHEUER. Wait a minute. Why are you not in a position to respond as fully as you would like?

Dr. MAHONEY. I will explain directly. It has nothing to do with someone telling me not to respond. It has to do with what I have been doing since I came to my job two months ago.

Mr. SCHEUER. Well, it also has to do with what you have been doing since 1982 as a diligent and participating member of this whole process, a very sophisticated—

Dr. MAHONEY. I don't dispute that at all, but I did want to point out that as all of my colleagues here at the table and many others will know, when I came to the position, I viewed that we had an absolutely critical need to pay attention to the process of the assessment planning. As a result, we have identified every one of the matters you have just spoken about as specific technical issues in dispute as needing careful review by me and by my principal technical colleagues. I have not yet conducted those reviews because I have spent the last two months, 12-hour days, trying to get the process on track.

I simply wanted to make clear for the record that I don't mean a hesitation or less than full response on some matters that you raised to mean that I have a judgment one way or the other. I am not trying to dispute some of the characterizations you make, but I did want to point out as a matter of process that in our program, coming in as the new director, I have given such full attention to getting the assessment plan structure started that I have had to take a reservation on going back to careful review of exactly the kinds of issues you have been citing.

Mr. SCHEUER. Dr. Mahoney, I respect that and I respect the effort you have put in on the subject of process that, as you know, is a deep concern to us, and I respect your very thoughtful and hopefully promising new initiatives to get this whole process question under control as the Congress intended it to be. I respect that and we are encouraged by it.

Let me just tick off a baker's dozen of areas in which we have profound reservations about not the great body of work but by this

artfully crafted executive summary that we think does such a disservice to the national understanding of the acid rain threat that we are faced with.

The executive summary defined acid lakes as those lakes with pH's of 5 or less, when going to 6 or less, which defines many of those lakes, would have given us ten times the number of lakes at risk. Ten times.

Excluding data on damage to Canadian lakes. Now, you may tell us there is a comparability problem. I just find it difficult to believe that if there had been a sincere, genuine effort to include the extraordinary damage that we have done to Canada by the flow of our pollutions from the Ohio River Basin up to Canada, clearly identifiable, predictable, quantifiable, we could have found a way to do it. The Canadians are deeply concerned about this. They have devoted their top scientific personnel to this. We find it a little hard to swallow that we couldn't have included the Canadian data into this summary because of comparability questions.

Reporting lake damages in terms of percentages of lake area rather than in numbers of lakes, which would have doubled or trebled the number of lakes involved.

Excluding small lakes under eight acres, which are even more vulnerable to acid rain damage.

Failing to quantify economic costs of acid rain damage. That goes to your central mission, integrating costs with benefits. The question of cost was totally left out.

Excluding information on episodic shocks which may cause significant acid rain damage, like heavy snowfalls.

Measuring lakes for pH in the fall when pH's are higher rather than in the spring when they are lower.

Excluding data linking emissions from midwest power plants to acid rain in the Northeast of the United States, all up and down the Atlantic Coast, and Canada.

Excluding available data on acidified streams.

Concluding that few, if any, additional lakes will become acidic in the Northeast when the best available information says we don't know.

Using unjustified optimistic assumptions about penetration of new technology, early retirement of power plants, growth in nuclear power to project a decline in sulfur dioxide emissions when all of these things fly flagrantly, transparently against what our eyes and ears and minds and intelligences tell us are the facts that we have to work with.

The disingenuous intellectual dishonesty of those pretensions really boggle the mind. They are not worthy of our government. They certainly are not worthy of you and the honesty and forthcoming fashion which you have testified this morning.

And finally, the conclusion that no abrupt changes in forests are likely, when the best available information here, too, is that we simply don't know.

Taking all of those matters, and I am just asking you as a matter of judgment, coming from a very professional, highly motivated individual, would you say that that executive summary that contains the features that I just mentioned is a fair and accurate summary of the two or three hundred pages of technical data which under-

girded that executive summary? Is that a fair and accurate summary?

Dr. MAHONEY. I believe that summary can and should be expanded and be made more representative of the full body of the information we have available.

Mr. SCHEUER. Well, Dr. Mahoney, I welcome that answer, and I would like you to tell us whether you would be willing to take the leadership, with your Interagency Scientific Committee involvement, in expanding it and perhaps going through an agonizing reappraisal and perhaps a redraft or a "Son of Executive Summary," and give us another executive summary in 30 or 60 or 90 days that would more or less set the record straight with the American public, with our Canadian friends, with our European friends, and perhaps help us focus a little better on what we should be doing and what is doable, what is cost-effective, what the challenge is, what we ought to be addressing ourselves to.

Do you think in the next month or two you might subject that executive summary to some thought and perhaps some recasting and redrafting?

Dr. MAHONEY. Mr. Chairman, I would be glad to do that. Can I make a constructive, I hope, and thoughtful answer that suggests a little broader context, though?

Mr. SCHEUER. Dr. Mahoney, you have been giving us constructive and thoughtful answers all morning. There is no reason why you should stop now. You have really been very encouraging. Do I take that as a declarative yes, that within 30 or 60 or 90 days we will have a recasting of that executive summary?

Dr. MAHONEY. Sir, I would like to suggest a different context, not a declarative yes to doing that, because I would like to point out a problem about our resource limitations.

Mr. SCHEUER. Dr. Mahoney, I am talking about a 35- page document that you could take home over a weekend. You could leave Friday night with that document in your hip pocket and come back Monday morning with a redrafting of that document or, let us say, another executive summary. That is not something that you couldn't do over the course of a weekend and still have the opportunity of looking at all those great Sunday morning political talk shows.

Dr. MAHONEY. Mr. Chairman, the problem is not the time that is required to redraft; it is the question of the time required to consider all the basis information again.

Mr. SCHEUER. How long would it take you to do that?

Dr. MAHONEY. I believe that kind of job could be done in three months.

Mr. SCHEUER. Accepted. Contract.

Dr. MAHONEY. But can I, before signing my half of that contract, point out—

Mr. SCHEUER. You made an offer and I accepted. That's a contract.

[Laughter.]

Dr. MAHONEY. No, sir.

Mr. SCHEUER. Let me throw a peppercorn at you. That really makes it a contract.

Dr. MAHONEY. No, sir. I answered a question about how long it would take. I want to put up the matter of the question of process that we are dealing with because I think I have a suggestion that might be helpful.

Mr. SCHEUER. Yes, please.

Dr. MAHONEY. And then I would like the sense of, of course, your direction.

The point is, as I described in my testimony, we have just embarked on an intensive job of trying to rationalize and write down the approach to planning this final assessment, including all of these matters of posing the questions to be answered very carefully and so forth, as I was describing and as laid out further in my statement. Now, you would already find in the shop and among the agencies people in, I would like to hope, let me say, happy turmoil these days. It is not onerous, in particular, but they are going to be very busy with that.

If we take the people necessary off of that job to reconsider and redraft a suitable summary—that is, to answer the sense of the questions that you have put—as a primary mission, we will slow down substantially the matter of getting this assessment plan process done, in my best view. They are the same people. I can't give thoughtful attention to both.

I am not trying to suggest either/or. I wanted to ask if you would be open to a different kind of suggestion. I wanted to put this matter of a problem.

Mr. SCHEUER. Let's hear your suggestion.

Dr. MAHONEY. My suggestion, then, is that I believe we could proceed with casting the plan I have been describing and, as appropriate, show where the existing information feeds into that plan and make that part of a resummary. The point is the 1987 interim assessment covered information available through early 1987. I can tell you, if we reconsider now, do we ask the scientists to say let's go back and look at only what we knew through January 1987, or should we take account of what we know for 15 more months, I can tell you you can't expect a responsible scientist to take that question lightly.

Mr. SCHEUER. Nor would I want him to. I would want him to include what we have learned in the last 15 months or so since that executive summary was published.

Dr. MAHONEY. Exactly.

Mr. SCHEUER. So maybe this is a sort of an easy way to back off a little bit, to say that you are reappraising that whole executive summary because we have new knowledge now. That is a sort of a face-saving device for everybody concerned. But I would hope, and I would like to get an expression from you that by Labor Day, which is four months from now, that you could recast this 35-page document and make it, as I say, a "Son of Executive Summary" that would include in it what we have learned in the last 15 months. That is less than ten pages a month.

If you have four months to do a 35-page executive summary, it is less than eight pages a month. That is about two pages a week. I think you can do that. I have full confidence that you can do that without interrupting the other very important ongoing work that

you have. Do you agree with me that you could crank out two pages a week for the next four months?

Dr. MAHONEY. I remember very well, Mr. Chairman, a statement made one time to me that a letter writer wrote: "I apologize for sending you a long letter; I didn't have time to write you a short letter."

Mr. SCHEUER. That is absolutely correct. Oliver Wendell Holmes said that.

Dr. MAHONEY. Yes. And I think we have to look at that in the matter of the two pages per week or month. I have no problem, no dispute about that, and the sense of the critiques and the sense of your questions are so broad that I agree we need to provide updated information, we need to provide an appropriate new summary.

What I want to be very careful about is I don't want to see us commit the resources to trying to rethink everything in midstream to the point that we take our eye off the ball of getting a good plan prepared and out for public review on the final products.

Mr. SCHEUER. Dr. Mahoney, normally I would pass over a matter of another recast of a 35-page executive summary, except that in this case it has had such a mischievous, destabilizing, disorienting, unfocusing, destructive result that has really shocked the scientific community into a sense of outrage. I mean you rarely see the GAO and the Congressional Research Service responding in the kind of lurid prose that they have responded to this executive summary. It was a very unusual piece of disingenuous persiflage, let me say.

I think it really deserves a revision, and I think the public and the scientific community and our friends in Canada and our friends abroad were shocked and horrified by it. It was so intellectually dishonest, and I think it cries for clarification, let us say, at its most charitable.

Dr. MAHONEY. Let me give my shortest answer of the morning: Yes, sir, I would be pleased to do that—

Mr. SCHEUER. Great. Give us a date. Labor Day?

Dr. MAHONEY. I think that would be a suitable time.

Mr. SCHEUER. Beautiful.

Dr. Mahoney, we have kept you far longer than we had expected or you had expected. We have covered a lot of ground. I think it has been a very constructive change. I talked to my Republican colleagues and my Democratic colleagues as we answered these couple of roll call votes. We have all been impressed by your demeanor, by your testimony, by your forthcoming attitude, and we are very much encouraged. We will wait eagerly for the appearance of a recasting and a reclarification of that executive summary by Labor Day.

And I just congratulate you. I'm very much encouraged by what we've seen and heard this morning. We very much appreciate your testimony, your patience and your good-humored spirit of cooperation. Thank you very, very much for coming up here. We look forward to working with you.

Dr. MAHONEY. Thank you indeed, Mr. Chairman. Thank you.

Mr. SCHEUER. We'll go to the panel number 2, with apologies that we've fallen so far behind schedule: Dr. Gene Likens, Director of the Institute of Ecosystem Studies at the New York Botanical Gardens; Dr. James Galloway, Department of Environmental Sci-

ences at the University of Virginia; and Dr. Joseph Goffman, of the Environmental Defense fund.

Well, I want to welcome you all; we're very happy to have you here. I take it you've been listening with interest to the proceedings over the last two and a half hours. Why don't each of you take about 8 or 10 minutes.

We do have to be out of this room by 1:00. But why don't each of you take 8 or 9 or 10 minutes and that'll take us to about 12:45, and then we'll have time for some questions.

So, let me recognize you in the order in which I introduced you: Dr. Gene Likens, and let me say for all of you that your prepared testimony will be printed in full at this point in the record. So give us a summary of your views, your testimony and don't hesitate to refer to anything that you've heard this morning, either from the witness table or from me and my colleagues.

STATEMENT OF DR. GENE LIKENS, DIRECTOR, INSTITUTE OF ECOSYSTEM STUDIES, THE NEW YORK BOTANICAL GARDENS; DR. JAMES GALLOWAY, DEPARTMENT OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF VIRGINIA; JOSEPH GOFFMAN, ESQUIRE, ENVIRONMENTAL DEFENSE FUND.

Dr. LIKENS. Thank you, Congressman Scheuer.

Mr. SCHEUER. Would you pull that mike closer, Dr. Likens?

Dr. LIKENS. Thank you, Congressman Scheuer. I've come today to talk about the Interim Assessment from NAPAP and to talk particularly about the Executive Summary which you have referred to several times this morning.

I've studied the four volumes of this report extensively, and enough to know that there are numerous errors and omissions and misstatements in it, as you have referred to. And in places, the report has been prepared quite carelessly, and as a scientist, that bothers me.

Mr. SCHEUER. Now, you're talking about the Executive Summary?

Dr. LIKENS. That's right.

Mr. SCHEUER. Thank you.

Dr. LIKENS. I am particularly critical of the Executive Summary which, in my opinion, badly misrepresents the general scientific understanding that we have about the problems of air pollution and particularly acid deposition. And I'm particularly concerned that the Executive Summary and, to a lesser extent, the entire report, ignores or discounts out of hand, the literally thousands of scientific papers that have been published on the topic.

Now it is true that many of these papers are listed in the NAPAP report, but they are neither discussed, evaluated or interpreted; so, as we call it in science, padding the reference list. Even though it has been pointed out that many of these papers are referred to in the NAPAP report, they have not been utilized. This point came forward just a little while ago, when you were talking about what we already know.

It's not as though we began to know and to learn everything about acid rain in 1980, when the NAPAP program started. There were thousands of papers published in scientific journals prior to

that time. And I would suggest that these need to be interpreted, included, evaluated, discarded if they're not good; used if they are.

I'd like to focus my criticism on the Executive Summary because of three important reasons which I'm sure are clear to you.

One, 5,000 copies of the Executive Summary were printed, whereas only 1500 copies of the 3 other more scientific volumes were published.

Secondly, particularly the news media and I would suggest, also the Congressional staff, will or have read only the Executive Summary. It's the impression that is given by it and its misrepresentation, that I am concerned about.

Thirdly, the Executive Summary is particularly deficient and misleading, and by selective reporting of what was in the rest of the volumes, has served to minimize the ecological damage caused by air pollution and acid deposition. As a scientist, that's what concerns me most.

I want to, given the limited amount of time that I have, and you have a copy of my formal testimony, I will not read—

Mr. SCHEUER. It will be printed in full in the record.

Dr. LIKENS. Thank you. I will not read it. I merely want to highlight just a couple of items, 3 to be precise, that typify some of my concerns—or characterize some of my concerns.

First of all, let me point out that on page 8 of the Executive Summary, it was stated and I quote, "... some lakes," and I emphasize some, "... some lakes and streams in sensitive regions, appear to have been acidified by atmospheric deposition at some point in the last 50 years." unquote.

This statement badly minimizes the effect of acid deposition, as numerous studies have shown recent acidification occurring in large numbers of lakes in the eastern United States.

In fact, my own research has shown that about 80 percent of the lakes in the Adirondack Mountain region of New York State, for which there are comparable historic data, have been acidified since the 1930's. And recent data from lake sediments in this same region, from Don Whitehead and Don Charles, show that these lakes began to acidify around 1950, and have been acidifying to the present, with no diminishment in rate.

So when you ask a question about, is the acidification likely to continue?; there are data that would suggest that it is likely to continue in that region. My colleague, Dr. Galloway will talk about other areas, I think, a little later on.

One of the concerns that I had about the Executive Summary was the sloppy scientific writing that occurred there in several places. For example, one of the articles dealt with ozone damage to plants, and the report and the Executive Summary had reproduced a scientific figure—an illustration that had appeared in *Science*.

Well, I took the time to go back and check the original paper, a paper published by Reich and Amundson in 1985 in *Science*, to determine whether it had been reproduced faithfully or not. And I found that, in fact, it had not.

Well, I'd been expressing some of my concerns about the problems in the Executive Summary, and Congressman Dingell asked me to identify them fully, which I did to him in a letter of 14 November. That letter was passed on to the Environmental Protection

Agency and the NAPAP group. Three and a half months later, I received an answer, and the answer that I got to that particular question, which was a question about sloppiness of presentation of data, was and I quote, "It is possible that the slope of the line for sugar maple may have been slightly steeper in figure 7-14, than in the original figure, however, this does not change the interpretation in the text." unquote.

In other words, the numbers may be wrong, but the answer is still the same. As a scientist, this answer really bothers me, in that the sloppiness that I was concerned about, seems to be continuing. And even the answer that says, it may be that the slope of the line was slightly different—well, it can be determined exactly, if it were or were not different.

Another example that I would refer to is that on page 10 of the Executive Summary, it was stated that, quote, "... man-made acid rain has been present in the eastern United States since the turn of the century." unquote. On the 6th of October, 1987, Dr. Kulp reiterated this same statement in a debate with me on live television, the CNN network.

In fact, there are no published data to provide for the support for the statement. There are published data that have been debated, argued about and so forth, that show that precipitation was not acid regionally prior to about 1930, in the eastern United States.

The response that I got back, as I mentioned before, from Mr. Thomas through Mr. Dingell, was and I quote, "... the paragraph on which Dr. Likens has commented, does not rely on either published or unpublished precipitation data, rather, it is clearly an inference from the patterns of emissions described in that paragraph." unquote. I'd like to read that again, "... that the paragraph on which Dr. Likens has commented, does not rely on either published or unpublished ... data ..."

Now, in science, when you make a comment that relies neither on published nor unpublished data, what is it based on? Well, I don't know. It's an inference, for sure, but when you make a statement in an Executive Summary that says man-made acid rain has been present in the eastern United States since before the turn of the century; that's a pretty powerful statement in an emotional, political context of which the acid rain issue is being debated. I suggest that is really bad science.

The last point that I would make very quickly, refers to a precipitation map of pH that appeared on page 24 of the Executive Summary. And I suggest that it shows unrealistically high values—that is, less acid than I would have expected in the northeastern United States in 1985. And if you would indulge me, I would like to show this figure quickly. Is there any chance of dimming the house lights?

This is the map that appeared in the Executive Summary of the NAPAP assessment. It's for 1985; it's annual precipitation weighted pH, and the bull's eye of this map, the pH 4.2, the lowest or the most acidic values, are shown there and they cover a small part of one, two, three, four, five states. And I was curious about this, so I went to our country's national monitoring network which is the National Atmospheric Deposition Program data.

They (NADP) had published a map for the same year, 1985. And I have plotted here, their data. I have not extrapolated them, manipulated them, or done anything to them, other than just plot them. And if you can see the darker, larger dots, those are the dots that have a pH of 4.2. And so the bull's eye, in fact, covers 11 states. And if Congresswoman Schneider were still here, she would see that the bull's eye covers her state in this map. But in the NAPAP assessment, it does not.

Now in terms of a report summarizing the information, I think it is quite clear that the difference in such a presentation clearly minimizes the effect. I have done nothing with those data, other than show them to you.

Let me quickly make a few concluding remarks. I think one of the major deficiencies in the assessment is the lack of consideration or evaluation of the relationship between pollutants. And that was referred to earlier this morning.

Although these interactions are referred to in a few places, the report continually comes back to what I would call a reductionist discussion of one single factor at a time, rather than the combined stresses which are what are affecting plants and lakes and humans and other animals in the environment. That's what's really going on. That's what we have to understand. That's very difficult.

Mr. SCHEUER. And you're suggesting, I take it, that there's a synergistic relationship between these polluting effects—

Dr. LIKENS. Absolutely.

Mr. SCHEUER.—where the whole may be greater than the sum of the parts?

Dr. LIKENS. And that's what we have to understand.

Mr. SCHEUER.—more dangerous and more polluting?

Dr. LIKENS. Yes, sir, the assessment must, in my view, carefully evaluate that kind of interaction.

The concentrations of sulfates, for example, the relationship between sulfates and nitrates and ozone, are important. The concentration of sulfates alone, even though they have decreased recently in the eastern United States, still are 2 to 4 times greater in rainfall than that thought to cause chemical and ecological change in sensitive aquatic ecosystems. If we add the dry deposition to that, then it is as much as 4 to 6 times greater than those acceptable levels.

Relative to the lakes that have been affected or changed by acid precipitation at this point, some have been acidified, according to the assessment. In the most recent issue of *Environmental Science and Technology*, an article by David Brakke, Dixon Landers and Joseph Eilers, Eilers being an employee of the U.S. Environmental Protection Agency, based upon this lake survey that you referred to earlier, Congressman, the last sentence in that paper's abstract, I would like to read to you, and I quote, "The data collected during the eastern lakes survey, support the hypothesis that regional lake acidification has occurred in the northeastern United States." unquote.

That, I would suggest, is a very different kind of statement than the ones that we find in the Executive Summary, which states that some may be, possibly, might have, and so forth.

As a scientist, I'm well aware of the use of the some and maybe and possibly and might have. In fact, you have criticized me in the past for being a one-handed scientist with, on the one hand it might be, and on the other hand it might not be, but—

Mr. SCHEUER. No, it's the one-armed scientist that we're all looking for, who doesn't give us the, on the one hand, on the other hand. You're a two-handed scientist.

Dr. LIKENS. I am, I am, and I agree. But, in fact, we do know a great deal about this problem, and my objection is that the Executive Summary does not state clearly what we do know and what we do not know.

Mr. SCHEUER. Dr. Likens, we've been at this stand for a long time, this Subcommittee, and over the years, we had top scientific officials whom we respected, who had credibility from NCAR, for example, in Boulder, come in and say to us, even though we really wanted to do something, we really don't know enough yet.

And that went on for quite a few years and they were giving us, on the one hand, on the other hand. But you know, all that has changed. And the responsible body of the scientific community now says, we don't need to do, on the one hand, on the other hand, anymore. We have enough credible scientific evidence to indicate that a certain minimal level of remediation, of control efforts, are justifiable by the scientific evidence, and that we can do things that are sensible, that will enable industry to compete, that are cost effective, and that we should get on with it.

That now, as I understand it—and please correct me if I'm wrong—is the consensus of the scientific community, and there has been a 180 degree sea change in the last 8 or 10 years that we've been having hearings on this subject.

Dr. LIKENS. It's difficult to know what the consensus of the scientific community is, but in 1985 a group of colleagues and I took the time to go through six federal reports prepared by scientists to look for answers to questions that we asked. A copy of that report is attached with my testimony, and the title of it is *Is There Scientific Consensus?*

It might be time to do that again, but the result of that look, not the answers we had, but the answers that were given in these other federal scientific reports, was, yes, indeed, there is a lot of consensus.

As I say, it might be time to do that again, because the ever-increasing amount of scientific information adds more and more to this knowledge base as we go along.

Mr. SCHEUER. Well, perhaps it would be possible for you and your colleagues to do this kind of reappraisal in the next four months so that you might have some views to give us at about the same time that Dr. Mahoney is going to have some rethinking and reappraisal to give us on that 35 page Executive Summary.

Dr. LIKENS. There has been in the meantime an additional report from the National Academy of Sciences, and this NAPAP report, for example, which adds a great deal of information.

I'd like just to finally say that the scientists working in the NAPAP program are largely very good scientists, and they do largely very good scientific work. I think they deserve better than they got in the Executive Summary of that assessment report.

As a scientist I feel badly that their work was not reported carefully and accurately; and that's what I believe, that it was not.

The other thing that I would like to say is that—

Mr. SCHEUER. Well, let me just say that I agree with you, and I think Dr. Mahoney agrees with you.

Dr. LIKENS. I hope he does.

Mr. SCHEUER. And I hope he does, too, and I think he does. He is a loyal employee of this Administration, but I detect that he was distancing himself from many of the conclusions in that 35 page Executive Summary.

And I suspect that one of the reasons he was doing it is, A, from his own hard knowledge as a professional and his many years, going back to 1982, of involvement in this area, and, B, I think he's probably quite well aware that there's extraordinary dissatisfaction and resentment and unhappiness in his own scientific advisory committee, and that there's a significant morale factor there, as a result of the fact that they don't feel that their work was properly integrated and summarized in a fair, objective, and intelligent way in that report.

And I think he's responding to their morale problems as much as he is to his own knowledge. That, as far as that report was concerned, that executive report, something was rotten in Denmark.

Dr. LIKENS. The last point that I would like to make is that, I think, NAPAP started in 1980, but the research really didn't begin until 1982. And, in my opinion, it's unreasonable to think that all of the important answers are going to be achieved by 1990.

When the program was set up as a 10 year program, that was a good target. But I think science doesn't work that way. There are always continuing questions and answers and revisions that are required.

So, I would like to suggest that we should continue that program as necessary, or some form of that program as necessary, and that we shouldn't put limits—even though I'm very critical of the report that came out last fall in 1987—this is a very complex issue and it is going to require a continual look. And, if we do apply legislative regulations and controls, we have to monitor those as well and see how well they are doing. That's a part of the continuing science.

[The prepared statement of Dr. Gene Likens follows:]

TESTIMONY TO THE SUBCOMMITTEE ON
NATURAL RESOURCES, AGRICULTURE RESEARCH AND
ENVIRONMENT
ON THE
NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM (NAPAP)

27 April 1988

My name is Dr. Gene E. Likens. I am Director of the Institute of Ecosystem Studies, Director of the Mary Flagler Cary Arboretum, and Vice President of The New York Botanical Garden. In addition, I am Adjunct Professor of Ecology at Cornell University, Professor of Biology at Yale University, and Professor in the Graduate Field of Ecology at Rutgers University. I co-authored the first paper about acid rain in North America (Likens et al., 1972), and I have published many papers on the topic of acid deposition during the subsequent sixteen years. I also am Co-Director of the Hubbard Brook Ecosystem Study, which has the longest, continuous record of precipitation chemistry in North America. I have authored or coauthored more than 250 scientific papers and seven books. I am a member of the National Academy of Sciences and of the American Academy of Arts and Sciences.

Today I want to comment on the recently released (autumn 1987) Interim Assessment Report from the National Acid Precipitation Assessment Program and on the Program itself. I have studied the four volumes of the Report enough to know that there are numerous errors and omissions, and in places the Report has been prepared quite carelessly. Although this Interim Assessment was published two years behind schedule, it still is not representative of what was known scientifically in 1985.

I am particularly critical of the Executive Summary, which badly misrepresents the general scientific understanding about air pollution and acid deposition, and either ignores or discounts out-of-hand the thousands of scientific articles published in high quality journals that show serious ecological damage caused by air pollution and acid deposition.

I focus my criticism on the Executive Summary because of three important reasons: 1) 5000 copies of the Executive Summary were printed, whereas only 1500 copies of the three other, more scientific volumes were published; 2) most, particularly the news media and Congressional staff, will read only the Executive Summary; and 3) the Executive Summary is particularly deficient and misleading, and by selective reporting minimizes the ecological damage caused by air pollution and acid deposition.

I want to summarize briefly some of the problems with the NAPAP Interim Report by providing some specific examples. These examples in no way represent an exhaustive review of the Executive Summary or of the other volumes, but are indicative of the problems found therein. I would recommend strongly that an exhaustive review and evaluation of the Interim Report be done by an unbiased panel of scientists. My comments follow:

1. The pH precipitation map on p. I-24 (see Attachment II) shows unrealistically high values for the northeastern United States during 1985. For example, the map indicates that the average pH at the Hubbard Brook Experimental Forest in New Hampshire would be about 4.4, or maybe even 4.5. The annual calendar-year pH at Hubbard Brook was, in fact, 4.30 and has never reached 4.40 during the 25-year record of measurement (see Likens et al., 1984; Likens, 1985). Moreover, a map for the same year prepared by the National Acid Deposition Program (NADP) gives significantly lower pH values (see Attachment III). Note particularly the much larger area in the NADP map that receives precipitation at a pH of 4.2. Thus the NAPAP map grossly misrepresents the size of the area receiving the most acid precipitation.

2. On p. I-10 it is stated that "...man-made acid rain has been present in the eastern United States since before the turn of the century." On 6 October 1987, Dr. J. Laurence Kulp, former Director of Research of NAPAP and author of much of the Interim Report reiterated this same statement on live television (CNN Network). There are no published data to provide direct support for this statement. In fact, the data which have been published (and debated) show that precipitation was not acid regionally prior to about 1930 in the eastern United States (see Cogbill and Likens, 1974; Cogbill and Likens, 1976; Likens and Butler, 1981; Butler et al., 1984; Cogbill et al., 1984).

3. Acidification of lakes and streams:

* p. I-8. "...no acidic lakes and streams (pH <5.0) have been found in the Southern Blue Ridge Province. . ." (on p. I-31 the Report states <6.0) is misleading and underlines one of the problems associated with the National Surface Water Survey (NSWS), e.g., only 54 small streams in this area were surveyed (p. I-31). Acidic surface waters have been found in this area, but I understand that Professor Galloway will discuss this point in detail in his testimony today.

* p. I-8. "Some lakes and streams in sensitive regions appear to have been acidified by atmospheric deposition at some point in the last 50 years." This statement badly minimizes the effect of acid deposition, as numerous studies have shown recent acidification in significantly large numbers of lakes in eastern North America (see work of Schofield, 1976; Norton, 1984; Gibson 1986; Asbury et al., 1988; etc.). My own research has shown that about 80% of the lakes in the Adirondack Mountain Region of New York State, for which there are comparable historic data, have been acidified since the 1930's. Recent data from D. Whitehead and D. Charles show that lakes which began to acidify in the 1950's in the Adirondack Mountain Region have been acidifying to the present with no diminishment in rate.

Organic acids play a relatively small role in the acidity of lakes in the Adirondack Mountain Region, as indicated by the lack of correlation between dissolved organic carbon (DOC) and pH (Vertucci, 1988; Brakke et al., 1987). Sulfate is the dominant anion (Driscoll and Newton, 1985; Overton et al., 1986; Brakke et al., 1988), and the major source of sulfur in the Northeast is from atmospheric deposition (e.g., Likens et al., 1977; Likens, 1985). The concentrations of acid neutralizing capacity (ANC) in some of the Adirondack lakes are among the lowest reported for the United States (Overton et al., 1986). The concentrations of dissolved aluminum (>200 ug/l) in many of these low pH lakes (Vertucci, 1988) are toxic to fish, especially in association with low concentrations of DOC (Cronan and Schofield, 1979; Driscoll et al., 1980; Baker and Schofield, 1980; Baker and Schofield, 1982). The NAPAP Report and, especially, the Executive Summary totally minimize or ignore this important interaction between acidity, DOC, and toxic metals in lakes in acid-sensitive regions of the northeastern United States.

* p. I-9. Statements like, acidified lakes "...represent a small fraction of the surface waters in the United States. . .," are quite misleading and minimize the impact in affected areas. Stating a fraction on the basis of the entire world or of the Universe would even further minimize the impact!

* p. I-30, etc. Use of pH <5.0 to define acidic surface waters grossly minimizes the effects of acid deposition. There are numerous published papers that show biological damage (including sport fish) at pH values less than about 6.0 (see, e.g., Schindler, 1988; Hall et al., 1980; Confer et al., 1983; a large number of European publications; etc.). As such, the report presents a biased and inaccurate impression about the effects of acid deposition on surface waters in sensitive regions of the United States.

4. The speculation that "...most watersheds in the glaciated Northeast are at or near steady state with respect to sulfur deposition . . ." is inaccurate and misleading. No one knows how to characterize "most watersheds," sulfate deposition in the Northeast is changing (Likens et al., 1984; Likens et al., 1985; Hedin et al., 1987), and such terrestrial ecosystems are unlikely to be in steady state (Likens et al., 1977; Bormann and Likens, 1979; Likens, 1985). From an ecological perspective, the report's use of the steady state concept is exceedingly naive. Also current changes in loading of sulfate probably will result in changes in acidity levels of surface waters (see Driscoll and Likens, 1982), but the effects will undoubtedly be delayed for up to several years in some regions (see, e.g., Galloway et al., 1988; Norton, 1984).

5. p. I-8, I-28, etc. In contrast to statements given on these pages, there are direct effects on foliage of plants by rain and cloud and fog water at ambient pH levels in the eastern United States (e.g., see Lovett et al., 1985; Evans, 1984; Jacobsen, 1984). Effects of air pollution and acid deposition on forests, crops, and other terrestrial ecosystems are very difficult to quantify because these systems are exceedingly variable and complex. Nevertheless, there is scientific evidence suggesting that acid

deposition (particularly for events of low pH, i.e., less than 3.5, which are not that uncommon) is damaging to plants.

Many rainfall events are well below a pH of 3.5, and a significant new factor is the high acidity of cloud and fog water (Weathers et al., 1986 [see Attachment IV]; Falconer and Falconer, 1980; Lovett et al., 1982; Waldman et al., 1982; Scherbatskoy and Bliss, 1984). The acidity of cloud water in the eastern United States frequently occurs in the range known to cause injury to plants under experimental conditions (Jacobsen, 1984; see Attachment V). In addition, highly acidic events may be coupled with high levels of ozone (Weathers et al., 1986) with high potential to cause plant damage. This topic is receiving intensive study currently in the United States (Jacobson, 1984; Moskowitz et al., 1985; Crang and McQuattie, 1986; Van Ryn et al., 1986).

Forest trees are generally unhealthy, growing slowly, or dying in several regions of eastern North America and western and central Europe. Recent studies indicate that air pollutants can adversely affect reproductive processes in northern hardwood forests (Van Ryn et al., 1986), can affect vital symbiotic, mycorrhizal fungal associations with tree roots (Reich et al., 1986a), can acidify soil (Nilsson, 1986; Hallbacken and Tamm, 1986), and can reduce net photosynthesis and growth in tree seedlings (Reich et al., 1986b).

6. A prime example of misleading, sloppy scientific writing is shown on p. I-28 and I-29 of the Executive Summary.

* The first paragraph under I. 3.8.2 refers to . . . "adverse effects on the foliage of conifer and hardwood species tested down to pH 3.5 (Fig. I-14)." However, Fig. I-14 refers to effects on diameter growth of seedlings, not foliage! Moreover, the ambient range of pH's used is not typical of summer rain and cloud water in the Northeast, and the species used in these studies are not typically found in the northern hardwood forests in the Northeast where problems of forest decline are most common.

* The first paragraph under I. 3.8.4 refers to ". . . decreased growth with ozone concentrations higher than about 50 ppb (Fig. I-15)." However, Fig. I-15 refers to "ozone exposure" in ppm-hr! I checked the original paper by Reich and Amundson (1985) and found that the regression line for sugar maple had been drawn improperly in the NAPAP Interim Report and that net photosynthesis had been replaced with "photosynthesis"! Moreover, Reich and Amundson (1985) state that, "The dose of O_3 in most of the eastern United States during a 10-week period in the summer ranges between 30 to 45 ppm-hr" (p. 567). Fig. I-15 indicates that the "ambient range" is about 9 to 14 ppm-hr! The same problems exist in Chapter 7 (see Fig. 7-14 on p. 7-33).

7. On p. I-9 it is stated that ozone damage to agricultural crops could produce a loss worth "a billion dollars per year." This statement also is repeated in the Synopsis for Chapter 6 (p. I-46). However, on p. I-26 it is stated that a reduction of about 20% in the daily mean ozone concentration could result in crop benefits on the order of a billion dollars. If a

reduction of 20% is worth a billion dollars, should not the total loss from ozone damage on crops be valued at \$5 billion? No critical evaluation was given in the NAPAP Report of OTA's (1984) assessment of crop loss due to air pollutants. Again, the known effects of air pollution have been minimized by the impressions generated in the organization and writing of this NAPAP Report.

On 12 November 1987 I wrote a letter to The Honorable John D. Dingell. This letter details many of my criticisms (see Attachment I) in response to his request for an evaluation of the NAPAP Interim Report. Two months after sending my letter to Congressman Dingell, I received a brief response from EPA via Mr. Dingell, and then one and one-half months later I received a longer response. Overall, these responses were ambiguous, inaccurate, and entirely unsatisfactory. In general, they represented bureaucratic rather than scientific responses. I still remain puzzled as to why it took three and one-half months for the "system" to respond to my five-page letter. Additional comments are made in my oral testimony.

Concluding Remarks

A truly major deficiency with this Interim Assessment is the lack of consideration and/or evaluation of the relationship between pollutants, and the interactions between pollutants and other environmental stresses. Although these interactions are mentioned in a few places in the Report, the Report continually reverts to a reductionist discussion of effects of single factors such as ozone, acid fog, etc., rather than combined stresses, which are what actually are impacting natural ecosystems.

A combination of factors can reduce vigor of individual plants to the point where any added stress can cause reduced growth or death. In addition, individual plants may respond uniquely to such stresses. The order in which stresses affect plants also may vary in space and time. For example, a prolonged drought, unseasonal temperatures, plus acute impacts from ozone and acid deposition may cause widespread forest decline where each of these factors acting independently may not. Such complexity of nature and biological response is common.

Anthropogenic pollutants affecting forest ecosystems are complex and variable in space and time, and may act singly or in combination with natural stresses. The complex mixture of pollutants affecting natural ecosystems have been referred to as a "pollution climate." In turn, these stresses act variably and simultaneously on the myriad of components within the forest ecosystem (e.g., microorganisms, plants, animals), each of which may be more or less sensitive in space and time to the various components of this pollution climate.

Currently, concentrations of sulfate in precipitation in much of the northeastern United States is ten to fifteen times greater than those in unpolluted, remote areas of the Southern Hemisphere (Galloway et al., 1984; Likens et al., 1987). Even though currently declining, wet deposition of sulfur in the northeastern United States is still two to four times greater than that thought to cause chemical and ecological change in sensitive aquatic ecosystems (see Dickson, 1983; Gorham et al., 1984; Nilsson, 1986;

Schindler, 1988). Inclusion of dry deposition would make these loadings of sulfur four to six times greater than acceptable levels.

The research funded by NAPAP did not begin until about 1982. It is unreasonable to expect that all of the important answers to this complicated issue will be apparent by 1990, even if the program had begun in 1980. Some answers may never be available! Thus, an arbitrary termination of a scientific program to assess an important environmental problem like acid deposition is neither reasonable nor cost effective. Nevertheless, the lack of all answers is not a prudent reason to delay legislative action to resolve the environmental problems caused by air pollution, including acid deposition. The scientific data about acid deposition, including those collected by the NAPAP scientists, convinces me and many other scientists that serious chemical and biological damage to natural ecosystems is occurring in the United States and will continue to occur if emissions of SO_2 and NO_x are not reduced. The rapid and "unexpected" forest decline in Europe is a sobering example of how badly natural ecosystems can be damaged if the early warning signs are ignored.

I have appended four additional items that may be helpful as you seek solutions to this complex and difficult issue (Attachment VI, "Acid Rain: A Summary"; Attachment VII, "Is There Scientific Consensus on Acid Rain?: Excerpts from Six Governmental Reports"; Attachment VIII, Bormann and Likens, 1987, "Viewpoint"); and Attachment IX, "Scientific Integrity in the NAPAP Interim Assessment: Remarks by Ellis B. Cowling").

Thank you.



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Gene E. Likens

12 November 1987

The Honorable
John D. Dingell
Chairman, Subcommittee on
Oversight and Investigations of
the Committee on Energy and Commerce
House of Representatives
Rayburn House Office Building
Washington, D. C. 20515

Dear Congressman Dingell:

I write in response to your letter of 5 October 1987 which requests a further review of the NAPAP Interim Assessment Report. I now have studied these four volumes enough to know that a detailed analysis (as you requested and as is needed) of this Report would take more time and funding than I have available. The Report must be studied carefully, as there are numerous errors and omissions; in places it has been prepared quite carelessly.

First, let me repeat my criticism of the Executive Summary, which you quoted in your statement of 2 October 1987. It badly misrepresents the general scientific understanding about air pollution and acid deposition, and either ignores or discounts out-of-hand the thousands of articles published in high quality journals that show serious ecological damage caused by air pollution and acid deposition.

I now have done additional, careful study of the Executive Summary and the supporting volumes, and this more detailed review has confirmed my original assessment. Let you think that I am alone in these criticisms, I would point out that numerous distinguished scientific colleagues, including Dr. David Schindler and Dr. Eville Gorham, both recipients of the prestigious G. E. Hutchinson medal for "excellence in research," presented by the American Society of Limnology and Oceanography, and Dr. James Galloway have spoken out strongly against the NAPAP Interim Report. Dr. Schindler has written to me in this regard and has pointed out how Dr. Lawrence Kulp, former Director of Research of NAPAP and author of much of the Report, misrepresented Dr. Schindler's criticisms of the Report. I have attached a copy of Dr. Schindler's letters for your information.

I originally focused my criticism on the Executive Summary because of three important reasons: 1) 5000 copies of the Executive Summary were printed, whereas only 1500 copies of the three other, more scientific, volumes were published; 2) most, particularly the news media and Congressional staff, will read only the Executive Summary; and 3) the Executive Summary was so deficient and misleading.

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Let me here briefly point out some of the problems with the Executive Summary by providing some specific examples. These examples in no way represent an exhaustive review of the Executive Summary or of the other volumes.

1. Fig. I-1 (p. I-2) is misleading and inaccurate. "Pure water" is rarely at pH 7; questionably high pH values for average annual rain, cloud water, and fog water are given (see Likens et al., 1984; Likens et al., 1985; and Weathers et al., 1986).

2. The pH precipitation map on p. I-24 shows unbelievably high values for the northeastern United States during 1985. For example, the map indicates that the average pH at the Hubbard Brook Experimental Forest in New Hampshire would be about 4.4, or maybe even 4.5. The annual calendar-year pH was, in fact, 4.30 and has never reached 4.40 during the 25-year record of measurement (see Likens et al., 1984; Likens et al., 1985). Moreover, a recent map for the same year prepared by the National Acid Deposition Program (NADP) gives significantly lower values for 1985 (see enclosed).

3. On p. I-10 it is stated that "...man-made acid rain has been present in the eastern United States since before the turn of the century." There are no published data to provide direct support for this statement. In fact, the data which have been published (and debated) show that precipitation was not acid prior to about 1930 in the eastern United States (see Cogbill and Likens, 1974; Cogbill and Likens, 1976; Likens and Butler, 1981; Butler et al., 1984; Cogbill et al., 1984). Rain may have been acid prior to 1930, e.g., locally in cities, but there are no published data.

4. Acidification of lakes and streams:

* p. I-8. "...no acidic lakes and streams (pH <5.0) have been found in the Southern Blue Ridge Province..." (on p. I-31 the Report states <6.0) is misleading (see the attached statement from Professor Galloway) and underlines one of the problems associated with the National Surface Water Survey (NSWS), e.g., only 54 small streams in this area were surveyed (p. I-31).

* p. I-8. "Some lakes and streams in sensitive regions appear to have been acidified by atmospheric deposition at some point in the last 50 years." Numerous studies have shown recent acidification in significantly large numbers of lakes in eastern North America (see work of Schofield, Charles, Whitehead, Dillon, NAS, etc.). Our own research has shown that about 85% of the lakes in the Adirondack Mountain Region of New York State, for which there are comparable historic data, have been acidified since the 1930's. Data from Whitehead and Charles show that lakes which began to acidify in the 1950's in the Adirondack Mountain Region have been acidifying to the present with no diminishment in rate.

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* p. I-30, etc. Use of $\text{pH} \leq 5.0$ to define acidic surface waters grossly minimizes the effects of acid deposition. There are numerous published papers that show biological damage (including sport fish) at pH values less than about 6.0 (see, e.g., Schindler, Schofield, Dillon, Hall et al., Confer and Likens, a large number of European publications, etc.). As such, the report presents a biased and inaccurate impression about the effects of acid rain on surface waters in sensitive regions of the United States.

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* The first paragraph under I. 3.8.4 refers to "...decreased growth with ozone concentrations higher than about 50 ppb (Fig. I-15)." However, Fig. I-15 refers to "ozone exposure" in ppm-hr!

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I checked the original paper by Reich and Amundson (1985) and found that the line for sugar maple had been drawn improperly in the NAPAP Report and that net photosynthesis had been replaced with "photosynthesis"! Moreover, Reich and Amundson (1985) state that, "The dose of O_3 in most of the eastern United States during a 10-week period in the summer ranges between 30 to 45 ppm-hr" (p. 567). Fig. I-15 indicates that the "ambient range" is about 9 to 14 ppm-hr! The same problems exist in Chapter 7 (see Fig. 7-14 on p. 7-33).

8. On p. I-9 it is stated that ozone damage to agricultural crops could produce a loss worth "a billion dollars per year." This statement also is repeated in the Synopsis for Chapter 6 (p. I-46). However, on p. I-26 it is stated that a reduction of about 20% in the daily mean ozone concentration could result in crop benefits on the order of a billion dollars. If a reduction of 20% is worth a billion dollars, should not the total loss from ozone damage on crops be valued at \$5 billion? Again, the known effects of air pollution have been minimized by the impressions generated in the organization and writing of this report.

9. The logic and order of presentation for the first paragraph under I. 3.7.1 and the last paragraph under I. 3.7.2 on p. I-25 defies imagination.

10. From a scientific point of view it should be noted that only fourteen references are cited for the Executive Summary (p. I-36), and just three of these were published in scientific journals. This is an excellent example of the poor utilization of the scientific literature.

* * * * *

I could add some additional review comments on other parts of the Report if they would be helpful, but before doing that, I would like to hear your specific answers/responses to the examples I've given above. As I mentioned earlier, such review requires a large time commitment, and I would like to be convinced that this effort is a profitable use of my time. After all, the Report represents the work of hundreds of scientists, and an expenditure of \$300 million. I am only one scientist with no funds to undertake a thorough review of this Report.

You mentioned in your statement of 2 October that the work of NAPAP was "just over half finished." Actually the research funded by NAPAP did not begin until about 1982. Also, it is unreasonable to expect that all of the important answers to this complicated issue will be apparent by 1990, even if the program had begun in 1980. Some answers may never be available.

The Honorable
John D. Dingell
12 November 1987
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Nevertheless, the lack of all answers is not a prudent reason to delay legislative action to resolve the problems of air pollution, including acid rain. For example, I would take issue with your conclusion that there is "no emergency." The scientific data about acid rain, including those collected by the NAPAP scientists, convinces me and many other scientists that serious chemical and biological damage to natural ecosystems is occurring in the United States and will continue to occur if emissions of SO_2 and NO_x are not reduced. The rapid and "unexpected" forest dieback in Europe is a sobering example of how "emergencies" can develop in natural ecosystems if the early warning signs are ignored.

I hope these comments will be useful to you as you seek solutions to this complex and difficult issue.

Sincerely,

Gene E. Likens
Director

Enclosures

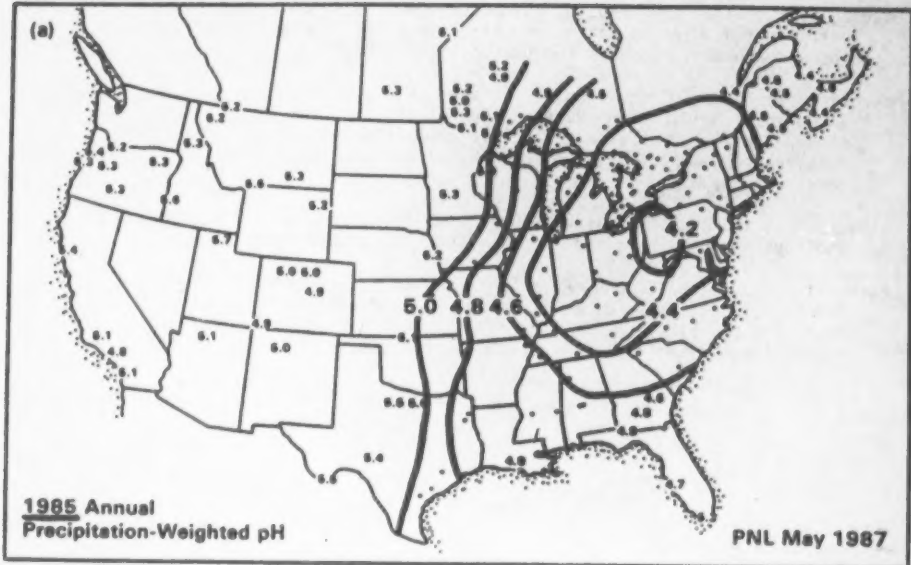
cc: The Honorable Thomas J. Bliley, Jr.
The Honorable James H. Scheuer
The Honorable Gerry Sikorski
The Honorable Jim Slattery
The Honorable Doug Walgren
The Honorable Henry A. Waxman
Michael L. Rodemeyer, Esq.
Dr. James N. Galloway
Dr. Eville Gorham
Dr. Gary M. Lovett
Dr. Michael Oppenheimer
Dr. David W. Schindler

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NAPAP INTERIM ASSESSMENT: VOLUME I





FROM: National Atmospheric Deposition Program. 1987.
NADP/NTN Annual Data Summary: Precipitation Chemistry
in the United States, 1985. Natural Resource Ecology
Laboratory, Colorado State University. Ft. Collins, CO.
340 pp.

A regional acidic cloud/fog water event in the eastern United States

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Cloud and fog water constitutes an important hydrological input to specific ecosystems¹⁻³. Recently, questions have been raised about the chemical composition of clouds and fog with reference to their potential role in adding chemicals such as nutrients, mineral acids and trace metals to such ecosystems. There are few data on the chemistry of cloud and fog water; those that exist suggest generally low pH values and high concentrations of major inorganic cations, anions and trace metals⁴⁻⁷, especially when compared with rain water collected from the same or nearby locations^{8,9}. Here we present the first analysis of a widespread, episodic cloud/fog event, using samples collected during August 1984 at six non-urban sites in the eastern United States. The pH was extremely low (2.8-3.09) and concentrations of sulphate and nitrate were 7-43 times greater than those for average precipitation at four eastern sites, and higher than previously reported values for cloud/fog water in the eastern United States. This suggests that such water may add ecologically significant amounts of pollutants and nutrients to many ecosystems in the region.

The Cloud Water Project (CWP), initiated in 1983 and coordinated from the Institute of Ecosystem Studies (IES) in Millbrook, New York, was designed as a synoptic study to make inter- and intra-site comparisons of cloud and rain water chemistry across a wide geographical area, ranging from Puerto Rico to Alaska. The 10 CWP sites are located in areas where cloud/fog water (for the purposes of this paper, fog is defined as ground-based cloud) is likely to be an important input of water and chemicals to natural ecosystems, such as coastal and montane regions. During this study, a widespread acidic cloud/fog event was detected in August 1984.

During the period 7-13 August 1984, samples of cloud and fog water with field pH values ranging from 2.80 to 3.09 were

collected from six non-urban sites (hereafter referred to by site identifiers noted in parentheses): Bar Harbor, Maine (ME); Mt Washington, New Hampshire (LC); Mt Lafayette, New Hampshire (GL); Mohonk Mountain, New York (MK); Hubbard Brook Experimental Forest, West Thornton, New Hampshire (HB) and Loft Mountain, Virginia (VA) (Table 1). Total sampling time at the sites varied from ~3 to 12 h; however, the total duration of the cloud/fog events is unknown.

Cloud/fog collections were made using a CWP Active Collector. This collector uses a battery-powered fan to draw atmospheric droplets through a ventral opening. It was designed so that cloud/fog water collections could be made at both high- and low-wind environments. Droplets are pulled at 7.6 m s⁻¹ across Teflon strands, where they are caught (50% efficiency at 5.2-µm drop size) and drip into a polyethylene collection bottle. Cloud/fog water samples were retrieved immediately after collectors were turned off, transported to a field laboratory, measured for pH using a modification of field techniques used by the Global Precipitation Chemistry Project^{10,11} and shipped to IES for chemical analysis.

Sulphate, nitrate, hydrogen and ammonium were the dominant ions in the samples collected from ME, HB, MK and VA, with sulphate and nitrate comprising ~95% of the measured anions, and hydrogen and ammonium ~95% of the measured cations. (Cation-anion balances were within ±10%.) Organic acids (acetic and formic acids) were measured in the MK sample using techniques described by Keene *et al.*¹². The absolute concentration of organic acids (50 µmol l⁻¹) for this cloud water sample was comparable to the highest concentrations reported for individual rain samples collected from central Virginia¹³. However, the sample was dominated by high concentrations of strong mineral acids, and therefore the percentage of organic acid contribution to total and free acidity was low (3 and <1%, respectively).

Sulphate and nitrate concentrations in cloud and fog water from ME, HB, MK and VA ranged from ~930 to 1,850 µequiv l⁻¹ (sulphate) (The contribution of sea-salt sulphate to total sulphate at all sites, calculated from methods described by Keene *et al.*¹² was <1%), and ~190 to 900 µequiv l⁻¹ (nitrate) (Fig. 1). These concentrations are 7-43 times greater than volume-weighted annual mean sulphate and nitrate concentrations in precipitation from locations in the eastern USA. Long-term means from Whiteface Mountain, New York¹⁴; Ithaca, New York¹⁵; Hubbard Brook, New Hampshire¹⁶ and Charlottesville, Virginia¹⁷ range from 44 to 61 µequiv l⁻¹ sulphate and 21-29 µequiv l⁻¹ nitrate. With the exception of the nitrate concentration in the VA sample, sulphate and nitrate concentrations of these cloud/fog samples are much higher than cloud water concentrations reported from other sites in New York and New England^{18,19} and lie within the range of values reported for urban fogs measured in Bakersfield, California, which are presumably formed in highly polluted conditions²⁰.

Before the acidic cloud/fog event, from 3 to 7 August, there was a large, stagnant high-pressure system over the eastern United States. A weakening low-pressure system moved from the north to the south on 7 August, during which time a very slow surface air flow continued to move from the Ohio Valley through the New York-New Jersey corridor and up the eastern seaboard. On approximately 8 August, a cold front stalled off the coast of New England and brought precipitation to much of the eastern United States. By 11 August surface air flow reversed, moving from the north-east to the south-west. The acidic cloud event that followed appears to have covered several thousand kilometres, and enveloped and wetted vegetation at most sites.

Vegetation in the eastern United States is frequently subjected to more than one anthropogenic stress. For example, on 7 August 1984, the day of the first acid fog collection from our Maine site, the State of Maine (Department of Environmental Protection) ozone monitoring station, located ~3 km from our ME CWP site, measured six continuous hours of ambient ozone

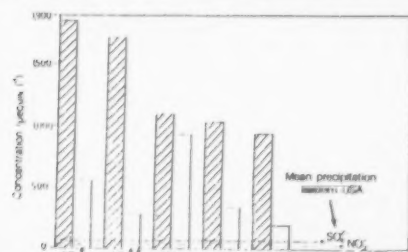


Fig. 1 Sulphate (■) and nitrate (□) concentrations of an acidic cloud/fog water event compared with mean precipitation from Whiteface Mountain, New York¹⁴; Ithaca, New York¹⁵; Hubbard Brook, New Hampshire¹⁶ and Charlottesville, Virginia¹⁷. Two-letter site identifiers are as in text. * Sample collected on 7-8 August 1984, ** sample collected on 8-9 August 1984.

Table 1 Location and elevation of cloud water project sites; date, sampling time and pH of acidic cloud/fog event

Site	Elevation (m above mean sea level)	Date	Sampling time (h)	Cloud/fog field pH
Bar Harbor, Maine (ME)	10	7-8 August 1984	1930-0730	2.90
Bar Harbor, Maine (ME)	10	8-9 August 1984	2130-0730	3.00
Bar Harbor, Maine (ME)	10	9 August 1984	0730-1530	2.95†
Mt Washington, New Hampshire (LC)	1,524	10 August 1984	1830-2230	2.97*†
Mt Lafayette, New Hampshire (GL)	1,220	10 August 1984	1830-2230	2.97*†
Mohawk Mountain, New York (MK)	467	11 August 1984	0910-1200	2.80
Hubbard Brook, New Hampshire (HB)	765	12 August 1984	0618-1200	2.97
Loft Mountain, Virginia (VA)	990	13 August 1984	1040-1500	3.09

* Samples from (LC) and (GL) were made by passive collection.

† Sample not of sufficient volume for chemical analyses.

concentrations ≥ 0.09 parts per million (range = 0.090-0.102 p.p.m.), thereby exceeding the state standard of 0.08 p.p.m. (ref. 15). Apparently, the vegetation surrounding our ME CWP site was subjected simultaneously to an acidic cloud/fog event and to high levels of ozone. Although the effects of combinations of acidic cloud/fogs and gaseous pollutants are poorly understood, acidic fog/gaseous pollutant combinations are known to produce different effects from those produced by gaseous pollutants alone¹⁶. Researchers have found that many plant species are damaged by ozone concentrations at levels reported for Acadia National Park on 7 August 1984 (ref. 15), and laboratory research has shown that acidic mists of pH ≤ 3.00 markedly increase leaching of substances from some vegetation^{17,18}, and that highly acidic mists cause necrotic lesions on the exposed leaves of lettuce¹⁹.

Since our cloud/fog water collections were made by active impact on an artificial surface, we are unable to estimate mass deposition rates of pollutants on surrounding vegetation.

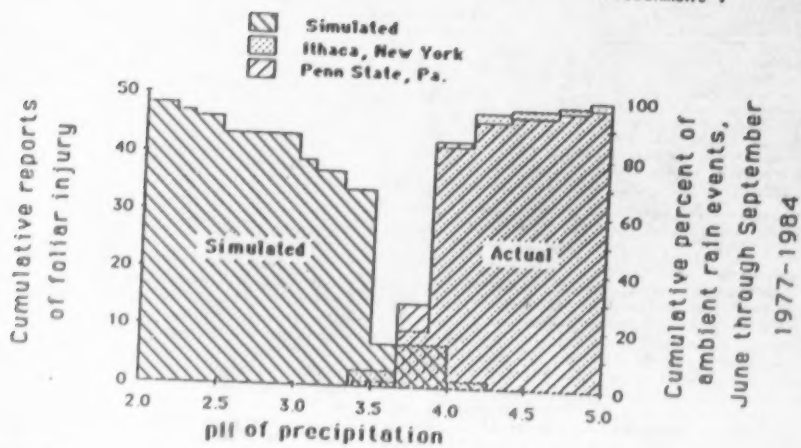
However, Lovett *et al.*⁴ have suggested that cloud water deposition in subalpine forests of New England is substantial.⁴ Our data from 7-13 August 1984 suggest that episodic exposure to highly polluted cloud/fog water is characteristic of a broad geographical range of coastal and montane ecosystems in the eastern United States. Additional information from Maine indicates that episodic extreme exposures of mixed pollutants must be carefully considered in evaluating air pollution effects.

To understand more fully the ecological effects of highly acidic cloud/fog episodes such as the event reported above, it is important to document further their frequency and intensity, and their rates of deposition to vegetation.

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(From Likens, 1988, as modified from Jacobson, 1984.)

ACID RAIN: A SUMMARY

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April 1988

ACID RAIN: A SUMMARY

Acid rain was identified as a regional problem in North America about fifteen years ago (Likens et al., 1972).

- Combustion of fossil fuels (coal and oil) adds oxides of sulfur and nitrogen to the atmosphere. Sulfur and nitrogen are returned to landscapes in wet (as sulfuric and nitric acids) and dry deposition. The dry deposition of acidifying substances contributes significantly to the environmental problems. Thus, acid deposition is a more informative term than "acid rain."
- In the intervening years, there have been more than 6,000 papers published about acid rain. Some of these papers are of high quality--some not--but they have been assessed by the scientific community, and it has been concluded in four reports by the National Academy of Sciences (1981, 1983, 1984, and 1986), reports of the President's Acid Rain Peer Review Panel (1983 and 1984), a report of the Canadian Acid Rain Peer Review Panel (1983), a report from the Office of Technology Assessment (1984), the Critical Assessment Review Papers for the National Acid Precipitation Assessment Program, the Memorandum of Intent Reports by the United States and Canada (1981-1983), and a report by Mr. Drew Lewis and Mr. William Davis, special envoys to President Reagan and Prime Minister Mulroney (1985), and in papers published by individual scientists that acid deposition is a serious environmental problem, and that major reductions in the deposition of sulfuric and nitric acids are necessary to alleviate the ecological effects which are widespread in the United States and Canada.
- These reports show that there are effects on lakes, streams, forests, crops, buildings, and structures, and other components of the landscape, but these effects are highly variable and complex. Nevertheless, the scientific evidence is convincing that the environmental problems are serious--an overall conclusion reached in all of the major summary reports!
- Recently, an ad hoc group of scientists reviewed these major scientific reports and found that a scientific consensus exists on a large number of important points regarding acid deposition and its effects (Driscoll et al., 1985).
- The variability and complexity of results have led to controversy, fostered largely by industrially-sponsored groups. However, the biological variability and complexity are understandable and expected when dealing with natural ecological systems--just as no two humans respond in exactly the same way to the common cold.

* Individual data are imperfect, but taken collectively, are convincing. As new data are obtained and published, they generally support the major conclusions.

- Industrially-supported efforts have generated a number of scientific "red herrings" (see Havas et al., 1984).
- Currently there is much debate in the United States about the political and economic ramifications of the "acid rain problem."

Atmosphere

- More than 90% of the emissions of SO_2 and NO_x to the atmosphere in North America is man-made. About 70% of the SO_2 and more than 30% of the NO_x emissions come from electrical utilities and smelters.
- Acid deposition occurs throughout eastern North America and at scattered locations elsewhere on the continent.
 - * The concentration of sulfur and nitrogen in rain and snow in the eastern United States is ten to fifteen times greater than in remote areas of the globe (Southern Hemisphere), where the average pH is about 5.0 (Galloway et al., 1984). [Figure 1]
 - * Currently about 65% of the acidity of precipitation in the eastern United States is due to sulfuric acid, and 35% is due to nitric acid.
 - It is thought that most of the environmental damage occurs because of the sulfuric acid (see Galloway et al., 1984; Driscoll and Likens, 1982).
 - * There has been a spread of acid deposition to the southeastern and midwestern United States during the last three decades (see Likens and Butler, 1981). [Figure 2]
 - * There have been reductions in emissions of sulfur in the United States during the last decade--this reduction is reflected in a reduction in concentration of sulfur and hydrogen ions in precipitation in the northeastern United States (see Likens et al., 1984; Hedin et al., 1987). [Figure 3] Even so, average annual wet deposition (concentration times amount of precipitation) of sulfur in the northeastern United States [Figure 4] is currently about three to four times greater than what is known to cause chemical change and ecological damage in sensitive aquatic ecosystems (see Dickson, 1983; Gorham et al., 1984; Nilsson, 1986; Schindler, 1988; Henriksen and Brakke, 1988). Inclusion of dry deposition would make these loadings of sulfur four to six times greater than acceptable levels.
 - * The concentration of lead in precipitation has decreased dramatically in precipitation in the northeastern United States following the Federal Government's restrictions of the use of leaded gasoline by automobiles (see Likens, 1983). [Figure 5]

- * On the average, cloud water in the northeastern United States is four to seven times more acid than rain water at the same locations. [Figure 6]
- * Cloud and fog water also may contain high concentrations of toxic metals, such as lead, and may be associated with high concentrations of ozone (Weathers et al., 1986).
- * In contrast to the rain water in remote regions of the Southern Hemisphere, rain water and especially cloud water in the eastern United States are highly polluted from anthropogenic emissions. [Figure 7]

Lakes

- A large number of lakes and streams in sensitive areas (areas with hard bedrock, thin, acid soils, and little neutralizing capacity) and those exposed to acid deposition have become acidified with concurrent losses of fish and other aquatic organisms. Historical evidence comes from:
 - * Changes in pH and alkalinity.
 - * Other changes in sediment and water chemistry.
 - * Changes in diatom populations.
 - * Changes in fish and invertebrate populations.
- Such data indicate that a large number of lakes and streams in Norway, Sweden, Denmark, Scotland, Canada, and the United States are more acidic than they were a few decades ago.
 - * New analyses of the historical changes in alkalinity of lakes in the Adirondack Mountains of New York State show highly significant acidification of a large number of Adirondack lakes in recent decades (Asbury et al., 1988).
 - * These changes are not explainable by other factors, e.g., changes in land use.

Vegetation

- Effects of acid deposition on forests, crops, and other terrestrial ecosystems are very difficult to quantify because these systems are exceedingly variable and complex.
- Nevertheless, there is scientific evidence suggesting that acid deposition (particularly short-term, acute acidification) may be damaging to plants. In a recent review (Evans, 1984), Evans stated:

-4-

"Presently there is evidence that the acidity in precipitation, at ambient levels, is having deleterious effects upon terrestrial vegetation. . . mostly derived from data of crops grown under field conditions."

- * Highly acidic events coupled with high levels of ozone and/or toxic metals and natural stresses can cause plant damage.
- Forest trees are generally unhealthy, growing slowly, or actually dying in many places in the United States.
 - * The so-called problem of forest decline is occurring in New England and other parts of the eastern United States, but the exact causes are not clear.
 - * Ozone and acid deposition contribute additional stresses to these plants.

Soils

- Soils require hundreds to thousands of years to develop.
- It is known from careful studies in the White Mountains of New Hampshire that rain at pH 4.6 can do things that rain at pH 5.6 cannot. For example, alumina minerals are essentially insoluble at pH 5.6, but are quite soluble at 4.6--in fact, one thousand times more soluble.
 - * Increased leaching of Al^{+++} (which is toxic to organisms) occurs at the lower pH.
 - * Rain and snow have not been above about pH 4.8 for the last ten years in the White Mountains of New Hampshire. The lowest value recorded was pH 2.85.
 - * Other changes occur in soil chemistry, e.g., in amounts and rates of sulfate adsorption, which, in turn, regulates the amount of sulfur entering surface waters.
 - * Soils may be acidified by acid deposition. [Figure 8]
- It has been proposed that acidity originates as organic acids from naturally-acidic soils.
 - * However, regional acidification of lakes and streams in North America have not been observed in areas which are not receiving acid deposition.
 - * The chemical and biological impact of acid involves not only the amount of acid present, but also the kind of acid anions present.
- Acidity in brown-water lakes and streams is caused by naturally-occurring organic acids, and such lakes have been acid for hundreds to

thousands of years; however, dissolved aluminum is bound to dissolved organic matter and is much less toxic in these brown-water lakes.

- The natural acidification of such brown-water lakes is not what is being discussed relative to problems of acid deposition.
- Sulfuric, not organic, acid dominates in recently acidified, clear-water lakes and streams in areas of North America receiving acid deposition. In such lakes and streams dissolved aluminum is much more toxic to organisms.
 - * From more than twenty years of intensive study at the Hubbard Brook Experimental Forest in New Hampshire, it is known that:
 - The sulfate content of stream water is highly correlated with sulfate content of precipitation. [Figure 9]
 - More than 50% of the hydrogen ion in the terrestrial ecosystem comes from acid deposition.
 - Headwater streams would have a pH of ~6.5 if there were no acid deposition; currently these streams have a pH of 4.9. [Figure 10]
- Overall, a gradual accumulation of effects results from acid deposition--e.g., an increase in sulfate content, a reduction in alkalinity.

Summary

- Acid deposition is a serious problem for aquatic and terrestrial ecosystems in sensitive regions of North America.
- Time scales for recovery are very different.
 - * Precipitation chemistry can change quickly.
 - * Lakes can recover in years to decades.
 - * Terrestrial systems can recover in decades to centuries.
- Such long-term or delayed responses suggest that the current effects are only the "tip of the iceberg."
- Accumulation of effects.
 - * Loss of alkalinity.
 - * Accumulation of sulfur in lakes and soils.
 - * Loss of bases from soil.

--- Thus, even though data are imperfect, it would seem to be prudent from a scientific basis to prevent such changes.

* It has been suggested that we should wait two to five years before acting to reduce emissions.

--- It is a fallacy to think that our scientific data base will be significantly improved in five or even ten years to the point where suddenly it will be apparent what the "absolute" regulatory action should be. Natural ecosystems are just too complex and too variable to expect such quick or absolute "answers."

On the basis of the scientific information reviewed, President Reagan's Acid Rain Peer Review Panel recommended (1984), "...that additional steps should be taken now which will result in meaningful reductions in the emissions of sulfur compounds into the atmosphere. . . ." "The overall scientific understanding of the various aspects of acidic precipitation is incomplete at the present time, and will continue to have major uncertainties well into the future. . . .For these reasons, any current scientifically-derived recommendations must be based on an imperfect, always increasing, body of pertinent data whose quality and completeness can be expected to improve for decades. Recommendations based on imperfect data run the risk of being in error; recommendations for inaction pending collection of all the desirable data entail even greater risk of damage."

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**FIGURE 1**

Enrichment of sulfate in precipitation in eastern North America above that in remote areas of the Southern Hemisphere (from Galloway et al., 1984).

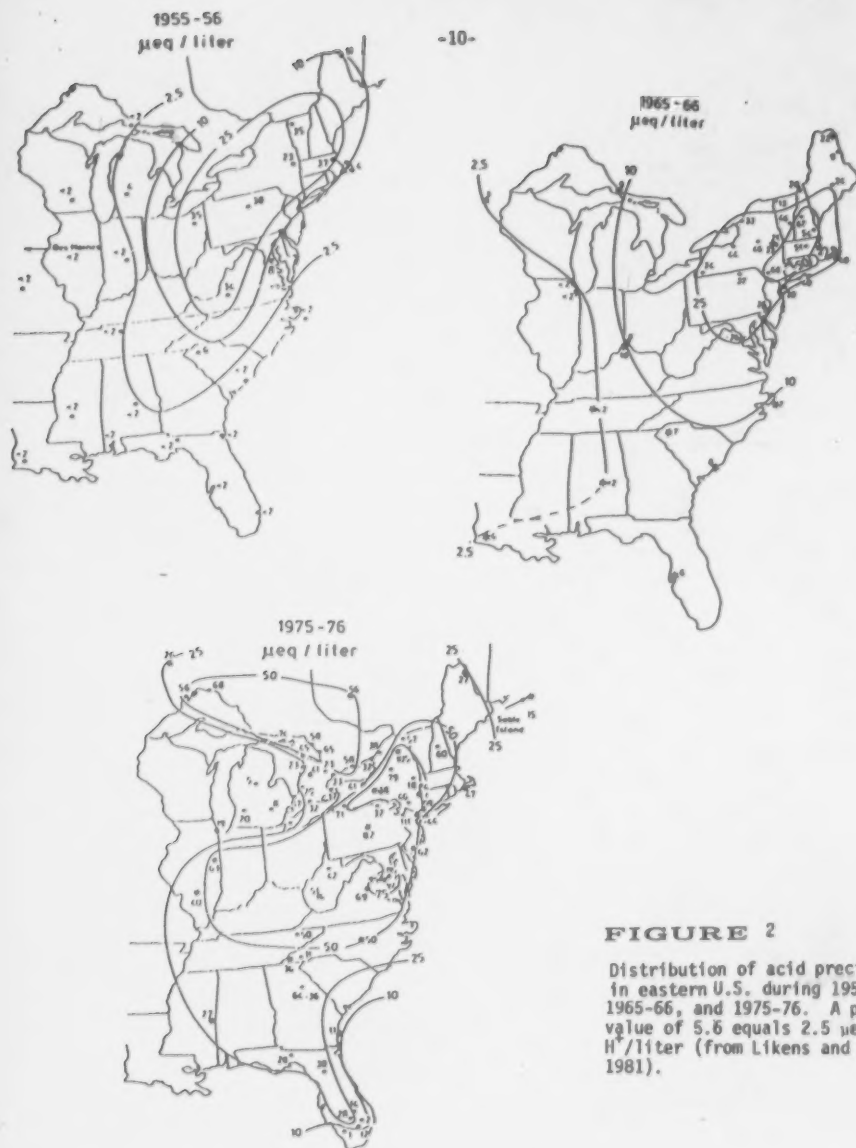


FIGURE 2

Distribution of acid precipitation in eastern U.S. during 1955-56, 1965-66, and 1975-76. A pH value of 5.6 equals 2.5 $\mu\text{eq H}^+/\text{liter}$ (from Likens and Butler, 1981).

-11-

FIGURE 3

Annual volume-weighted concentration (mg/liter) in precipitation at the Hubbard Brook Experimental Forest, New Hampshire from 1964 to 1984.

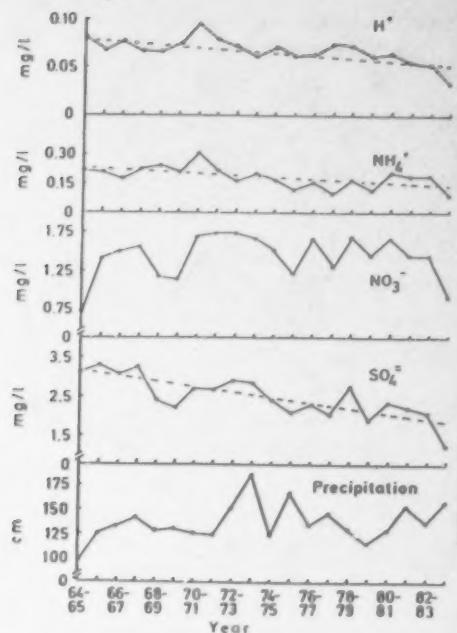
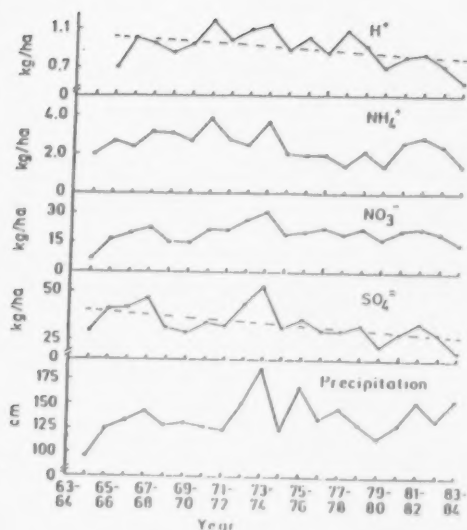
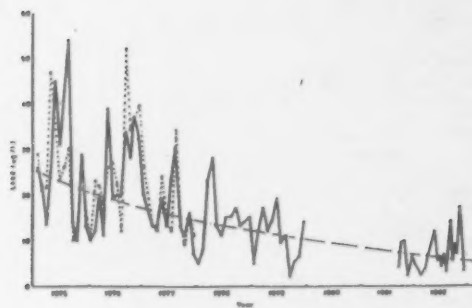


FIGURE 4

Annual deposition (kg/ha) in precipitation at the Hubbard Brook Experimental Forest, New Hampshire, from 1964 to 1984.

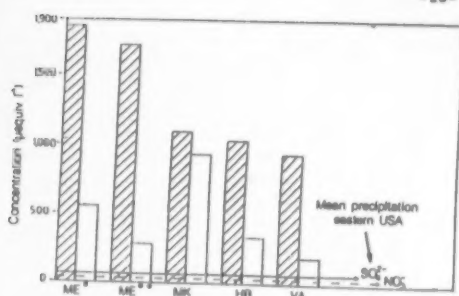


-12-

**FIGURE 5**

Concentration of lead in precipitation
at the Hubbard Brook Experimental Forest,
New Hampshire, from 1975 to 1983 (from
Likens, 1983).

-13-



(From: Weathers et al., 1986.)

Fig. 6 Sulphate (▨) and nitrate (□) concentrations of an acidic cloud/fog water event compared with mean precipitation from Whiteface Mountain, New York¹³; Ithaca, New York¹³; Hubbard Brook, New Hampshire¹⁴ and Charlottesville, Virginia¹³. Two-letter site identifiers are as in text. *Sample collected on 7-8 August 1984; ** sample collected on 8-9 August 1984.

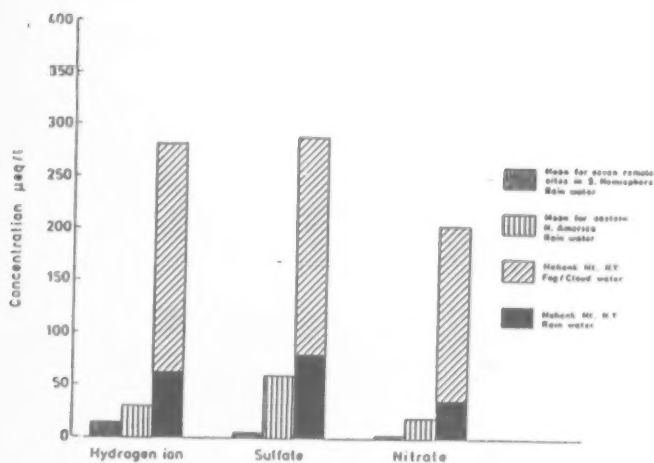


FIGURE 7

A comparison of the average chemistry of precipitation in remote sites in the Southern Hemisphere, in average precipitation in eastern North America (both modified from Galloway et al., 1984) and in cloud and rain water at Mohonk Mt., New York during 1984 and 1985.

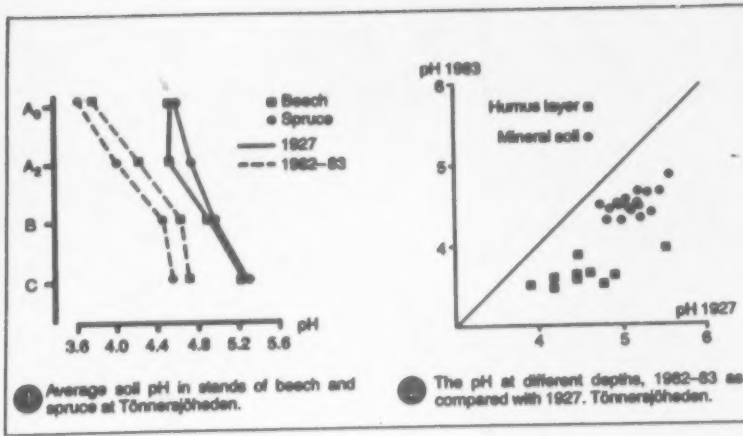


FIGURE 8

Fifty-five year changes in pH of soil in Sweden (from Tamm and Hallbacken, 1986).

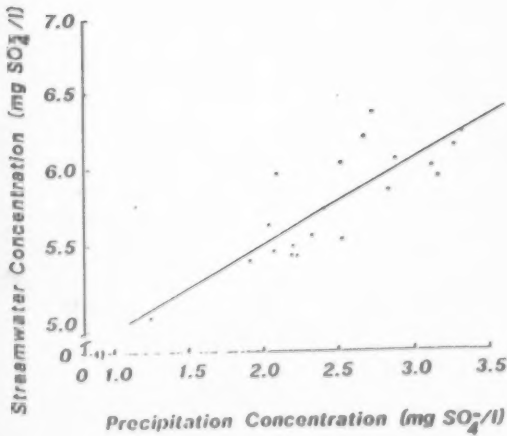


FIGURE 9

Relationship between the annual concentration of sulfate in precipitation and the annual concentration of sulfate in stream water at the Hubbard Brook Experimental Forest, New Hampshire, from 1964 to 1984.

-15-

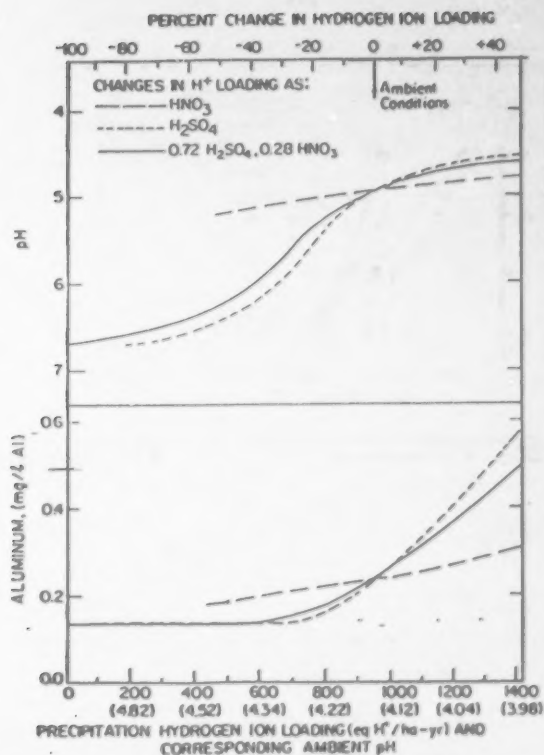


FIGURE 10

Projected changes in annual volume-weighted mean stream-water pH and aluminum concentration for changes in hydrogen ion loading through precipitation at the Hubbard Brook Experimental Forest, NH. These changes were calculated as if the change in loading occurred as only nitric acid, only sulfuric acid and a combination of nitric and sulfuric acid corresponding to the ambient stoichiometry of Hubbard Brook precipitation. The lower limits of decreases in HNO_3 and H_2SO_4 loading are governed by average concentrations of nitrate and sulfate in ambient precipitation. The abscissa is expressed as hydrogen ion loading in precipitation (eq H^+ / ha-yr), ambient precipitation pH and percent change in precipitation hydrogen ion loading. (Modified from Driscoll and Likens, 1982.)

IS THERE SCIENTIFIC CONSENSUS ON ACID RAIN?

**Excerpts from six
governmental reports**

**Ad Hoc Committee on Acid Rain:
Science and Policy**

October 1985

16 October 1985

To Those Concerned with Resolving the Acid Rain Issue:

Over the past four to five years, the Congress has considered various amendments to the Clean Air Act designed to address acid rain. These bills have typically called for reductions in sulfur, one of the major precursors to acid rain. Congress is once again considering sulfur-control legislation.

During these few years, we as research scientists have perceived that the barrage of conflicting views and information presented by the media, in published reports, and in congressional testimony has created an impression of scientific confusion and uncertainty on major aspects of acid rain in the minds of policymakers, regulators, and the public. We believe that neither the Congress, the Executive Branch, nor the public is well served by an appearance of scientific uncertainty when the actual state of scientific knowledge is considerably more certain.

Based on our own research and review of the scientific literature, we are convinced that the scientific community now understands at least qualitatively--and in some cases quantitatively--the sequence of physical and chemical steps that lead from emission of oxides of sulfur and nitrogen in North America to eventual changes in widespread ecosystems, as well as the consequences of increasing or reducing the emissions of sulfur, nitrogen, and other air pollutants. The biological consequences of high rates of sulfur deposition on aquatic ecosystems are particularly well understood.

In light of these views, we formed an ad hoc committee to review six major scientific reports prepared by scientists and sponsored by the Executive Branch or the Congress. Our review sought to assess the degree of scientific consensus on major chemical, physical, and biological issues relevant to increased acid-rain controls. The result of our review is the attached document entitled "Is There Scientific Consensus on Acid Rain?". For 17 major scientific issues of acid rain, it excerpts relevant sections from the reports. Collectively, the excerpts show that strong scientific consensus exists on the major issues, even though uncertainty remains and further research is warranted. Even in areas where these documents indicate that large uncertainties remain, i.e., the precise contribution of sulfur

-2-

or nitrogen compounds to forest degradation, they show a general consensus, in this case that air pollution can stress forests. Lastly, we believe that these governmental reports establish a scientific consensus that reducing the emissions of a large number of air pollutants, most notably sulfur dioxide, would benefit biological systems in North America significantly.

Yours very truly,

Charles T. Driscoll, Ph.D.

James N. Galloway, Ph.D.

James F. Hornig, Ph.D.

Gene E. Likens, Ph.D.

Michael Oppenheimer, Ph.D.

Kenneth A. Rahn, Ph.D.

David W. Schindler, Ph.D.

Please contact the Institute of Ecosystem Studies, The New York Botanical Garden, Mary Flagler Cary Arboretum, Box AB, Millbrook, New York 12545, for additional copies of the report.

INTRODUCTION

A group of scientists and others concerned with public policy met on September 24, 1984 at the Mary Flagler Cary Arboretum in Millbrook, New York, to consider the role of scientific information in formulating policy for regulating acidic deposition. The participants in the meeting, listed in the Appendix, perceived appreciable confusion and lack of awareness about the scientific information on acidic deposition which had been generated during the past 15 years. With a view to determining the extent of scientific consensus on major aspects of acid deposition, the scientists at the meeting created an *ad hoc* committee to compile statements on several key questions from six governmental reports (Table 1) of the past four years. Members of the committee were C. Driscoll, J. Galloway, J. Hornig, G. Likens, M. Oppenheimer, and K. Rahn. Additional material was provided by D. Schindler of the Freshwater Institute, Winnipeg, Manitoba and by R. Friedman of the Office of Technology Assessment, Washington, D.C.

This document is the result. It presents a series of direct quotations from the reports which in the aggregate show that scientific consensus exists on a number of significant points regarding acid deposition and its effects.

Funding for this project was provided by the Mary Flagler Cary Charitable Trust.

Table 1. The six governmental reports cited in this document.

- | | |
|-------|--|
| CARP | The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Review Papers, Volumes I,II. USEPA Report EPA-600/8-83-016A, July 1984 |
| NAS-1 | Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion, National Research Council, National Academy Press, 1981 |
| NAS-2 | ACID DEPOSITION: Atmospheric Processes in Eastern North America: A Review of Current Scientific Understanding, National Research Council, National Academy Press, 1983 |
| NAS-3 | Acid Deposition: Processes of Lake Acidification, National Research Council, National Academy Press, 1984 |
| OSTP | Report of the Acid Rain Peer Review Panel, Office of Science and Technology Policy, July 1984 |
| OTA | Acid Rain and Transported Air Pollutants: Implications for Public Policy, Report OTA-O-204, Office of Technology Assessment, U.S. Congress, Washington, D.C., 20510, June 1984 |

MAJOR AREAS OF CONSENSUS IN THE SIX REPORTS

1. What are the sources of acid deposition?

Man-made emissions of SO_2 and NO_x are the dominant contributors to acid deposition. Natural sources of these pollutants seem to account for less than 10% of total atmospheric loadings. Sulfur compounds are responsible for about two-thirds of the acidity in precipitation; nitrogen compounds, one-third.

These pollutants are frequently transported hundreds of miles, so that distant sources routinely add significantly to the contributions from more-local sources.

Acidity is deposited in both wet and dry forms. Wet deposition ("acid rain") is generally used to represent acid deposition because it can be measured more reliably than dry deposition can. Both wet and dry deposition acidify ecosystems, however.

2. How extensively has acid deposition damaged the environment?

Acid deposition can acidify streams, lakes, and soils. Acidification can change biological populations and communities as well as reduce the number of species in them.

Long-term acid deposition, particularly of sulfuric acid, has acidified surface waters in the northeastern United States and southeastern Canada to the extent that certain species of fish and insects have been reduced or occasionally eliminated. A host of other biological effects has also been noted. Acidification and associated biological effects have been found where sensitive surface waters receive acid deposition.

Acid deposition can acidify soils, especially those which are moderately acid initially. Acidification decreases the availability of nutrients and thus alters biological communities in soil. Acid deposited on leaves can leach nutrients which, if not replaced, will affect the trees. Some forests in eastern North America have been increasingly damaged during the past few decades; acidity alone or in conjunction with other pollutants such as ozone may contribute.

In addition to affecting biological communities in sensitive surface waters and soils, acid

deposition and its precursors also decrease atmospheric visibility and corrode materials.

3. What will happen if we reduce the emission of SO_2 ?

Reducing the emission of SO_2 throughout a multistate region such as the eastern United States will reduce the deposition of sulfur over the same region commensurately.

Depending on its magnitude, a reduction in deposition will reduce or eliminate several types of damage to resources such as:

- acidification of aquatic ecosystems
- degradation of visibility
- soiling and damage to materials.

Reducing the emission of SO_2 will also reduce the exposure of crops, forests, and human populations to acidifying compounds of sulfur. The extent of benefits to these resources is more controversial, however, because the causes and extent of damage are less certain than for the former groups of resources.

4. What is the relationship between scientific information and policy?

Scientific information is necessary but not sufficient to determine policy. Environmental policymakers receive information on the extent of known and anticipated damages caused by certain practices, together with information on possible remedies. They then decide whether to alleviate some or all of the damages by comparing their societal importance to the societal consequences of changing the practices responsible for them.

Policymakers who are convinced that the identified damages to lakes, streams, materials, and visibility are unacceptable will advocate a policy to reduce them. Policymakers who believe that the identified damages are too small to justify action may require additional evidence or greater certainty regarding causes and remedies, however.

Substantial consensus exists on sources of acid deposition, on certain types of damage

caused by the deposition, and on likely effects of reducing the emissions responsible for the acidity. Adequate scientific information exists to select emission-reduction strategies to reduce acid deposition efficiently.

CITATIONS FROM THE SIX GOVERNMENTAL REPORTS

I. Questions on the atmosphere

A. *What fraction of sulfur and nitrogen emissions and deposition in eastern North America are man-made? What are the most important types of man-made sources?*

"In eastern North America, emissions of SO_2 and NO_x from human activities appear to be at least ten times larger than emissions from natural processes." (OSTP, p. III-1)

"Averaged over Eastern North America (east of the Mississippi and south of James Bay in Canada), natural background sources might contribute about 12 to 25 percent of the total. Another group has estimated natural sources of sulfur to be about 5 to 10 percent of manmade sources in this same region.

Natural background is estimated to contribute similar proportions of total wet nitrate deposition—about 10 to 25 percent when averaged over Eastern North America." (OTA, p. 279)

"Present evidence does not show that natural sources of sulfur compounds are significant contributors to excessively low precipitation pH when compared to anthropogenic sources." (CARP I, p. 2-102)

"On a quantitative basis and for the area of the United States east of the Mississippi River, soil-generated natural sources of sulfur compounds are estimated to total about 0.07 Tg S yr^{-1} . Thus, less than 1 percent of the sulfur compound emissions in this regional area seem to be due to natural sources, even though this natural source estimate might vary by a factor of 2 or 3." (CARP I, 2-102)

"Only a few percent of the NO_x contribution to acid precipitation may be due to natural NO_x sources." (CARP I, p. 2-102)

"For example, in eastern North America (i.e., east of the Mississippi River), 90 to 95 percent of precipitation acidity may be the result of human activities, although natural sources may also be important at times in specific locations." (NAS-2, p. 13)

"There are no known natural causes that can account for either the distribution or the value of acidity in eastern North America. The region of highest acidity does, however, correspond to

the regions of heavy industrialization and urbanization along the Ohio River Valley and the Eastern Seaboard, where anthropogenic emissions of sulfur dioxide, nitrogen oxides, and hydrocarbons are high." (NAS-2, p. 13)

"For the Nation overall, the major sources of sulfur dioxide emissions—about 90 to 95 percent of the total—are electric-generating utilities, industrial boilers, and industrial processes. Similarly, three sectors—utilities, mobile sources, and industry—produce more than 95 percent of the country's manmade nitrogen oxides emissions." (OTA, p. 57)

"The largest increases in SO_2 emissions over this period (1950-1980) occurred in the Southeast, where nearly 90 percent of the total sulfur oxides emitted are attributed to electric utilities and industrial fuel combustion sources." (CARP I, p. 2-106)

"Copper and nickel smelters represent the major Canadian SO_2 source category, with most point sources located in eastern Canada." (CARP I, p. 2-107)

"Electric utilities and highway vehicles are the largest contributors to NO_x . Highest NO_x emissions densities occur in the northeastern United States and are influenced by highway vehicles. Coal-fired utilities significantly affect the NO_x emissions in the Midwest." (CARP I, p. 2-107)

What fraction of the acidity of precipitation originates in sulfur and nitrogen compounds?

"In the East, sulfur compounds currently contribute about twice as much acidity to precipitation as nitrogen compounds." (OTA, p. 16)

B. *What is the characteristic lifetime and scale of transport for sulfur in the atmosphere?*

"Pollutants emitted into the atmosphere can return to earth almost immediately or remain aloft for longer than a week, depending on weather patterns and the pollutants' chemical interactions." (OTA, p. 5)

"Substances that are highly reactive—e.g., NO , HCl , SO_2 , HNO_3 —and/or have a high solubility in water—e.g., NH_3 , SO_2 —or hygroscopicity—e.g., aerosols of NH_4NO_3 and $(\text{NH}_4)_2\text{SO}_4$ —are fairly rapidly removed; that is, their residence

times are on the order of hours to a week." (NAS-1, p. 57)

"The North American data therefore suggest that whatever atmospheric processes are taking place, pollutants are being thoroughly mixed over a region with linear dimensions up to 1,000 km." (NAS-2, p. 9)

Can both distant and local sources affect deposition at remote receptors?

"There exists now no acceptable method for determining source-receptor relationships on a scale much smaller than 'eastern North America'....Even if a verified model is developed in the future, the source-receptor relationship may be found to be sufficiently complex and variable that emission controls would still need to be assigned over large areas rather than locally." (OSTP, p. III-4)

"Preliminary analyses suggest that about one-third of the total amount of sulfur compounds deposited over the Eastern United States as a whole originates from sources over 500 kilometers (km) (300 miles) away from the region in which they are deposited. Another one-third comes from sources between 200 and 500 km (120 to 300 miles) away, and the remaining one-third comes from sources within 200 km (120 miles)." (OTA, p. 5)

"Based on modeling simulations for summer conditions, one may identify three approximate regions in northeastern United States and eastern Canada in which the relative contributions to acidic depositions due to emissions from near (<500 km) versus distant (>500 km) sources may be significantly different. In the upper Ohio River Valley (a dense source region), sources within 500 km appear to dominate the maxima of ambient SO_2 and aerosol sulfate concentrations, as well as the total wet and dry depositions of sulfur. At the other extreme, in upper New England and parts of eastern Canada which are remote from major sources of sulfur, long-range transport may be responsible for most of the aerosol sulfate and total wet deposition of sulfur. In the intermediate regions, including the Adirondacks, contributions to total acidic depositions from near and far sources may be more comparable, considered on a regional and summer average basis. These simulations have a minimum resolution of about 100 km and thus do not reflect local source 'hot spots'." (CARP I, p. 3-90)

"Recent studies of air-mass trajectories at Whiteface Mountain in the Adirondacks indicate that 62 percent of the sulfate ion and 65 percent of the nitrate ion are deposited by precipitation

associated with air parcels emanating from the Ohio River Valley and midwestern States." (NAS-2, p. 103)

"The evidence of the air-parcel trajectory studies at specific receptor sites in remote areas of the northeastern United States suggests that the industrialized region to the southwest is a major source of both nitric and sulfuric acids deposited at the sites." (NAS-2, p. 108)

"The spatial distribution of the annual average molar ratios of pollutants in emissions and deposition suggest that atmospheric processes in eastern North America lead to a thorough mixing of pollutants over a wide geographic area, making it difficult to distinguish between the effects of local and distant sources." (NAS-2, p. 140)

C. What are the relative contributions of wet and dry processes to deposited sulfur and nitrogen?

"A substantial fraction of such (SO_2 and NO_x) emissions returns as sulfate and nitrate in rainfall; a comparable amount returns as "dry" deposition through surface-interaction processes which are more difficult to monitor than "wet" deposition." (OSTP, p. III-2)

"Averaged over the Eastern United States, about equal amounts of sulfur compounds are deposited in wet and dry forms. However, in areas remote from pollution sources, such as the Adirondacks, wet deposition may account for up to 80 percent of the sulfur deposited; in urban areas near many sources of pollution the situation is reversed." (OTA, p. 5)

"As a rule of thumb, for sulfur and nitrogen compounds at least, dry deposition is taken on the average to be about as effective as wet deposition in pollutant removal. About one third of sulfur emissions is transported out of the continent. Thus roughly one third of northeastern emissions is assumed to be dry-deposited on the North American continent." (NAS-2, p. 46)

D. How do wet deposition, dry deposition, total deposition and precipitation acidity vary with changes in sulfur dioxide emissions?

"On the global scale, the sulfur system is clearly linear, for all the sulfur emitted is deposited (sulfur does not accumulate in the atmosphere the way longer-lived constituents such as carbon dioxide and the Freons do). On the smallest scale, sulfur is highly nonlinear, for it is easily transported away from the point of emission. On intermediate scales, such as the size of

eastern North America, the degree of linearity must be intermediate." (OSTP, p. VI-11)

"Reducing sulfur oxide emissions will reduce the total amount of acid formed in the atmosphere, if levels of nitrogen oxides and hydrocarbons remain constant, and chemical reactions are not limited by a shortage of oxidizing agents. Furthermore, given these conditions, a decrease in sulfur dioxide emissions should decrease total sulfur deposition by an approximately equal proportion. Where deposition will decrease can only be estimated on a regional scale." (OTA, p. 73)

"Assuming that the ambient molar concentrations of NO_x and basic substances (such as ammonia and calcium carbonate) remain unchanged, we conclude that a reduction in sulfate deposition will result in at least as great a reduction in the deposition of hydrogen ion." (NAS-2, p. 84)

"On the basis of currently available empirical data and within the limits of uncertainty associated with the data and with estimating emissions, we therefore conclude that there is no evidence for a strong nonlinearity in the relationships between long-term average emissions and depositions in eastern North America." (NAS-2, p. 31)

II. Questions on aquatic ecosystems

A. Have lakes and streams in the United States been acidified by acid rain?

"Acid precipitation contributes to the greater-than-natural hydrogen-ion levels in some lakes and streams in eastern North America" (OSTP, p. III-2)

"There is no question that fresh water bodies in sensitive areas have been altered." (OSTP, p. III-5)

"Substantial evidence indicates that acid deposition alters water chemistry in sensitive lakes and streams." (OTA, p. 41)

"Although there can be significant problems with comparing old and new data, overall, the analysis of temporal records shows recent decreases in alkalinity and pH in some otherwise undisturbed streams and lakes in areas receiving acidic deposition. As yet, no body of evidence exists suggesting that changes of such magnitudes, and at such rates, occur in otherwise undisturbed areas not receiving acidic deposition." (CARP II, p. 4-167)

"Although acidic waters do not occur naturally, in some cases, and changing land use may

locally alter the pH regime of surface waters, it appears that regional acidification and episodic pH depressions ($\text{pH} < 5.0$) in clearwater oligotrophic lakes and streams occur only in response to increased atmospheric deposition of strong acid. In areas not receiving acidic deposition, but with identical changes in land use, regional acidification of clearwater oligotrophic surface waters has not occurred." (CARP II, p. 4-168)

"Due to acidic deposition, SO_4^{2-} concentrations have increased in aquatic systems in much of eastern North America. The increase in SO_4^{2-} problem has to have been matched by an increase in C_B or H^+ . Since aquatic systems with original low alkalinities are characterized by watersheds with low $\text{C}_\text{B}/\text{H}^+$ ratios in the soil, a large portion of the increase in SO_4^{2-} will have to be matched by an increase in H^+ , i.e., decreased alkalinity." (CARP II, p. 4-112)

"There is empirical and theoretical evidence for lake and stream acidification." (NAS-3, p. 10)

B. What are the estimates of the past, current and future rates of acidification?

"...about 3,000 lakes and 23,000 miles of streams have already become acidified, or have so little acid-neutralizing capability left that they are extremely vulnerable to further acid deposition. This corresponds to about 20 percent of the lakes and streams found in identified sensitive areas." (OTA, p. 43)

"If sulfate deposition were decreased by 20 percent, OTA estimates that 10 to 25 percent of these water bodies might show improvement. If sulfate deposition were reduced by 30 percent, about 15 to 40 percent might show improvement. If sulfate deposition were increased by 10 percent, OTA estimates that acid-alteration of lakes and streams might intensify by about 5 to 15 percent." (OTA, p. 43)

"Scandinavian and North American studies appear to agree on one point: acidification of sensitive waters is detectable within one to two decades where pH values of precipitation are less than 4.6—a 10-fold increase in acidity over the theoretical "pure" rain pH value of 5.6. In areas where precipitation has pH values of 4.0 to 4.3, degradation is much more rapid. Changes in the pH or alkalinity of water bodies of small areas of Belgium, the Netherlands, and Denmark also have been recorded." (NAS-1, p. 153)

"Theoretically, in lakes and streams impacted by acid deposition, where sulfate concentrations are still increasing, the alkalinity will continue to decrease. With respect to lakes and streams affected by acid deposition, where sulfate con-

centrations are stable, there is disagreement in the panel as to whether future alkalinity decreases will be gradual over the period of centuries or perceptible over years to decades. The disagreement stems from a lack of data." (NAS-3, p. 11)

C. Are there biological changes due to acidification of lakes and streams?

"Although some kinds of lakes have been acid throughout their known history, others in areas subjected to acid deposition have become appreciably more acid during the past few decades. These changes in lake acidity have been accompanied by major changes in the biological activity within them, often including the disappearance of various aquatic biota, most visibly fish." (OSTP, p. III-2)

"In lakes near very strong sources of sulfur dioxide, such as the smelters of Sudbury, Ontario, ecological effects have been severe. Thus, there can be no doubt that high loadings of acid can destroy the normal biology of a lake." (OSTP, p. V-4)

"Fish are sensitive both to the acidity of water, and to toxic metals—primarily aluminum—that are released from the watershed under acid conditions. When waters become more acid than pH 5, many fish species are eliminated and major changes in lake ecosystem processes frequently occur. High acidity, toxic concentrations of metals such as aluminum, or some combination of the two appear to cause these changes." (OTA, p. 42)

"Biological effects due to acidification occur for a few species near pH 6.0. Because the biological response to acidification is a graded one, continued pH declines below pH 6.0 will result in escalating biological changes, with many species adversely affected in the range pH 5.0 to 5.5. Long-term declines in pH, commonly to pH 4.5 to 5.0, have been observed for a number of lakes and streams in areas receiving acidic deposition. For the same waters, historical data and paleolimnological analyses indicate that pH levels were often mid 5's or higher prior to acidification. In addition, episodic depressions down to pH 4.4 to 4.9 often occur in low alkalinity waters during periods of snowmelt and heavy rainfall and can affect systems with a pH as high as 7.0. These pH levels, along with other changes associated with the acidification process (e.g., increased aluminum, clarity, accumulation of detritus and algal mats), will have significant harmful effects on aquatic organisms. In waters where pH values average below 5.0, most fish

species, virtually all molluscs, and many groups of benthic invertebrates will be eliminated. Increased aluminum concentrations may eliminate fish species otherwise tolerant of low pH. The plankton community will be simplified and dominated by a few acid-tolerant taxa. Benthic algal mats will often cover the lake bottom, and water clarity may increase. These represent the best documented effects of acidification. Effects on ecosystem processes remain largely unconfirmed and are an important area for future research efforts." (CARP II, p. 5-159)

"Addition of acidic deposition to terrestrial and aquatic systems can disrupt the natural biogeochemical cycles of some metal and organic compounds to such a degree that they can cause biological effects. The chemical form of dissolved metals is important in determining the total mobility of a metal and the biological effects related to acidification of aquatic ecosystems. Acidification increases the concentration of many metals in surface waters and changes speciation toward more biologically active forms." (CARP II, p. 4-168)

"Acid deposition, due to the further oxidation of sulfur and nitrogen oxides released to the atmosphere by anthropogenic sources, is causing widespread damage to aquatic ecosystems, including loss of bicarbonate, increased acidity, and higher concentrations of toxic metals. As a result, several important species of fish and invertebrates have been eliminated over substantial parts of their natural ranges." (NAS-1, p. 182)

"If lakes and streams have been acidified by acidic deposition then biological effects will follow. Because the chemical changes are for the most part gradual and variable, 15 years is too short a period over which to evaluate biological trends. However, streams and lakes acidified by acidic deposition have a different biotic structure than nonacidified streams and lakes." (NAS-3, p. 4)

D. If sulfur emissions are reduced, how long will it take lakes and streams to return to their previous chemical and biological conditions?

"Lakes and streams require years or decades to recover from anthropogenic acidification once the acidic inputs are removed, with the recovery time depending on local geochemical factors, flushing rates, rates of species colonization, extent of alteration of trace-element composition, and other factors." (OSTP, p. III-5)

"These systems have responded to increases in acid deposition in the past and will respond to future changes in acid deposition. In

watersheds that retain significant quantities of sulfate, lakes and streams that have responded more slowly to acid deposition will continue to respond to past levels of acid deposition and will exhibit slow response to any future increases or decreases in acid deposition." (NAS-3, p. 8)

III. Questions on terrestrial ecosystems

A. Does acidic deposition alter forest ecosystems?

"Forest damage has been increasing in eastern North America during the past few decades; acid deposition may be a contributor." (OSTP, p. III-2)

"Acid deposition might be harming trees in two ways: either directly (e.g., by removing nutrients from leaves), or indirectly, by altering the soils on which trees grow....Acid deposition might be stripping such essential nutrients as calcium and magnesium from these soils, or releasing metals, such as aluminum, that are toxic to plants. Whether this nutrient loss or release of metals from the soil is large enough to affect forest productivity at current levels of acid deposition is unknown." (OTA, p. 12)

"At present we have no direct evidence that acidic deposition currently limits forest growth in either North America or Europe, but we do have indications that tree growth reductions are occurring, principally in coniferous species that have been examined to date, that these reductions are rather widespread, and that they occur in regions where rainfall acidity is generally quite high, or pH is low (< pH 4.3) for an annual average." (CARP II, p. 3-63)

"Addition of acidic deposition to terrestrial and aquatic systems can disrupt the natural biogeochemical cycles of some metal and organic compounds to such a degree that they can cause biological effects. The chemical form of dissolved metals is important in determining the total mobility of a metal and the biological effects related to acidification of aquatic ecosystems. Acidification increases the concentration of many metals in surface waters and changes speciation toward more biologically active forms." (CARP II, p. 4-168)

B. Does acidic deposition alter soils?

"Acid deposition can remove essential nutrients such as calcium and magnesium from the soil, but the rate of removal—the importance relative to other factors—is difficult to determine.

Moderately acid soils are thought to lose nutrients at a faster rate than more acid soils, but the more acid soils typically have less nutrients." (OTA, p. 45)

"Though relatively rare in the Eastern United States, some moderately acid soils might further acidify from nutrient loss over decades of exposure to acid deposition. About 1 to 5 percent of the Eastern counties (depending on the soil criteria used) are dominated by soils of this type." (OTA, p. 45)

"Increased leaching of potassium, calcium, aluminum, and magnesium due to ion exchange reactions with hydrogen ions is one of the most commonly observed effects of acid precipitation. These increased rates of leaching appear to outstrip compensatory increases in weathering, reducing the exchangeable pool of the above cations." (NAS-1, p. 173)

"The long-term effect (i.e., over decades or centuries) of acidic deposition can be expected to remove cations from forest soils, but it is not clear whether this will reduce available cations and enhance acidification of soils. For example, cation leaching rates, although increased by acid precipitation, may remain insignificant relative to total soil supplies and forest growth requirements; furthermore, exchangeable cations may be replaced by weathering from primary minerals at rates sufficient to maintain their current status partially as a result of acid precipitation inputs." (CARP II, p. 2-55)

"The soils most susceptible to rapid acidification are well-drained brown forest soils (alfisols) that are sandy and noncalcareous but not already strongly acid. Such coarse soils are moderately to highly saturated by "basic" cations such as Ca^{++} , Mg^{++} , K^{+} , and Na^{+} , which are leached away as they are replaced by "acid" cations such as hydrogen ions, aluminum ions, and hydroxy-aluminum ions. As the exchange complex becomes dominated increasingly by the "acid" cations, the pH of the soil declines. Fine-textured mineral soils, because of their high clay content, have a much greater cation-exchange capacity, which is usually strongly saturated by "basic" cations, and such soils are much better buffered against acidification.

Strongly acid podzol (spodosol) soil horizons—whether organic, with a high cation-exchange capacity, or sandy, with low cation-exchange capacity—are only slightly susceptible to further acidification. Their exchange sites are already dominated by the "acid" cations, and thus added hydrogen ions are more likely to pass through the system in the percolating water. Nevertheless, because such soils are already im-

poverished, even slight losses owing to increased acidification may be critical for soil fertility." (NAS-1, p. 172)

"Another important terrestrial effect of acid deposition may be on cycling of nutrients by bacteria, blue-green algae, and fungi. For instance, pHs of 3.2 inhibit mineralization of glucose in soils, pHs of 3.0 to 4.0 reduce decomposition of plant litter, and pHs below 6.5 decrease sulfur reduction in soils. Because the cycling of nutrients is such a critical function of the biosphere, any adverse effect could be significant. More research in this area is needed, particularly in wetlands, lake and river sediments, and terrestrial soils." (OSTP, p. V-9)

"Forest soils may be altered by acid deposition with either beneficial or harmful results. The nitrates and sulfates from acid deposition can supply essential plant nutrients. In many areas, nitrogen in the soil is in short supply; on these soils nitrates in acid rain might improve forest productivity. Sulfur-deficient soils, however, are quite rare. On nutrient-poor acid soils, especially those where sulfate can travel freely through the soil, further nutrient loss—even at a slow rate—from the soil, forest canopy, and decomposing plant material might be significant. About 15 to 20 percent of the Eastern counties meet these criteria, but whether nutrient loss is significant enough to affect near-term forest productivity is unknown." (OTA, p. 45)

"A number of soil microbial processes appear to be affected by acidification. Reduced soil pH may cause a reduction in nitrogen fixation, although mineralization of organic nitrogen may increase. Increased acidity also causes nitrification to decrease; nitrification usually ceases entirely at about pH 4.0. There may be some degree of acclimation in acid environments. Denitrification, the main means by which nitrogen is released to the atmosphere from the biosphere, is also affected by acidification. Decreased rates, and a change in end product from molecular nitrogen to nitrous oxide, are observed in anoxic environments at pH values less than 6.0. At lower pH levels an appreciable yield of nitric oxide is observed, which is phytotoxic." (NAS-1, p. 177)

"It appears that the detrimental effects of acidification on soils may not be due to—or at least, wholly attributable to—acidification *per se* but may be caused by the altered concentrations of nutrients and heavy metals in acidified soils. Direct toxicity of hydrogen ions in soils was found to be negligible over the pH range 4 to 8; around pH 3 roots may be injured and above pH 8 phosphate absorption may be inhibited. In

general, pH affects plant growth—by influencing the concentrations of different ions in the soil solution. Some of the elements affected are major plant nutrients (e.g., calcium, potassium, phosphate, nitrate), while several trace elements (e.g., manganese, copper, zinc) may be nutrients at low concentrations and toxicants at high concentrations, as for example around metal smelters." (NAS-1, p. 179)

"Short-term studies indicate that increased H^+ loading will cause increased loss of cations and organic components from forest litter. Over the longer term, the biologically mediated mineralization of organic matter in forest soils will be only slightly inhibited by acidic deposition (< 1 to 2 percent decrease in decomposition rate). Unless average precipitation inputs were to drop to pH 3.0 or below, significant impacts of acidic deposition on litter decomposition in natural systems are not expected." (CARP II, p. 2-55)

"At high concentrations, acidity can release, or 'mobilize,' aluminum from soil minerals; this may lead to toxic effects on biota in both lakes and forest soils." (OSTP, p. III-5)

"Naturally acidic soils occur fairly extensively, being the predominant soil type in about half the counties east of the Rocky Mountains covered by forest or rangeland. In about one-third of these acidic soils, the strong, freely moving acids from acid deposition can release aluminum and other toxic metals from the soil. However, whether toxic metals are released in sufficient quantities to affect forest productivity is unknown." (OTA, p. 45)

"Differences in effects of different levels of acidification upon trace metals in soils are even less well understood. The only detailed study is that ... in which purely organic *mor* humus layers from Swedish spruce forests were leached in the laboratory by simulated rain acidified to 5 different pH levels. Two sets of humus layers were examined, one far from and the other near to a brass mill. The simulated rain at pH 4.2...released (over 125 days) substantial percentages of several trace metals in the control humus layers, notably manganese..., nickel..., cadmium..., and zinc... Percentage release was much less for the other metals, copper..., vanadium..., chromium..., and lead... With the notable exception of vanadium release..., percentage releases were generally less in the humus layers of the polluted site..." (NAS-1, p. 173)

"Aluminum toxicity may affect forests on already acid soils when acidic deposition plus natural acidifying processes increase acidity enough to cause a significant rise in Al availability. If soil pH is low enough (pH 5.0 to 5.5) in

mineral soils to cause the dissolution of Al- and Mn- containing minerals. H^+ input will increase release of Al and Mn to the soil solution." (CARP II, p. 2-55)

"Addition of acidic deposition to terrestrial and aquatic systems can disrupt the natural biogeochemical cycles of some metal and organic compounds to such a degree that they can cause biological effects. The chemical form of dissolved metals is important in determining the total mobility of a metal and the biological effects related to acidification of aquatic ecosystems. Acidification increases the concentration of many metals in surface waters and changes speciation toward more biologically active forms." (CARP II, p. 4-168)

C. Does acidic deposition affect trees and plants directly?

"...terrestrial effects of acid precipitation may be extremely important, and may rival or exceed those in surface waters. Laboratory experiments have shown that acid deposition adversely affects both plant growth and foliage. In the natural environment, however, the effects are not so clear because acid rain is only one of several stresses on plants, some others being ozone, SO_2 , metals, and droughts. Also, it is often difficult or impossible to distinguish effects of direct deposition to the exposed plant from effects of increased ground-water acidity or leaching of essential micronutrients on root systems." (OSTP, p. V-8)

"Acid deposition can remove essential nutrients such as calcium and magnesium directly from tree foliage. If the rate of nutrient loss is greater than can be replaced through the roots, nutrient deficiency will result. Scientists do not know which tree species are most susceptible to foliar nutrient loss, or the level of acid deposition at which such loss becomes harmful." (OTA, p. 44)

"Available experimental results do not appear to indicate that the negative effects of acidic precipitation outweigh the positive effects, however, many crops and agricultural systems have not been properly or adequately studied." (CARP II, p. 3-63)

IV. Does acid deposition damage structures and monuments?

"While there is strong evidence for damage to limestone monuments, bridges, buildings, and other structures from SO_2 and other corrosive gases, there is no good estimate of the economic

magnitude of these effects or of the contribution from acid deposition." (OSTP, p. III-5)

"Air pollution damages a broad range of materials—including building stone, rubber, zinc, steel, and paint. Ozone is the pollutant that most affects rubber, while many other materials are chiefly affected by sulfur oxides. Humidity plays a key role in materials damage—dry-deposited sulfur dioxide and sulfate that dissolve on moist surfaces (forming concentrated sulfuric acid) may cause greater damage than relatively less acidic rain. Since air pollution is only one of many environmental factors (e.g., temperature fluctuations, sunlight, salt, micro-organisms) that cause materials damage, it is difficult to determine what proportion of damage it accounts for. Moreover, it is difficult to determine the proportion of materials damage caused by transportation pollutants as opposed to local pollution sources." (OTA, p. 46)

V. Do compounds of sulfur and nitrogen affect visibility?

"...degradation of visibility by fine-particle acidic aerosol is real and widespread. While it is true that its effects show up most clearly in the West, where virtually unlimited visibility surrounding scenic vistas is expected, we differ from Work Group I on the relative importance of visibility there. Preoccupation with the West is largely cultural. Eastern North America has many regions with great vistas which are widely valued when seen. When weighted for the larger number of people in the East, we believe that maintaining visibility there is at least as important as in the West. Once one becomes attuned to atmospheric optics, reduced visibility can be just as annoying over distances of 5 miles as over 150 miles." (OSTP, p. V-10)

"Sulfate concentrations correlate well with visibility impairment over large regions of the United States; in the East, sulfate appears to be the single most important contributor to visibility degradation. Recent studies suggest that sulfates account for 70 percent of visibility impairment during the summer, and 50 percent annually, in the Eastern United States. Nitrates rarely contribute substantially to visibility degradation in the East. However, in the Western United States, windblown dust and nitrogen oxides can also reduce visibility significantly." (OTA, p. 47)

"At eastern rural sites sulfate accounts for a large part of the fine particle mass and the light extinction." (CARP II, p. 5-82)

"At western locations nitrate and carbon-containing particles make a substantial contribution to fine particle mass and to light extinction." (CARP II, p. 5-83)

VI. Do acid deposition and its precursor pollutants affect human health?

"We accept the assertion that acidic deposition does not directly affect human health. Even indirect effects such as increases in aluminum or lead in water supplies appear to have no immediate health effect, although they should be monitored." (OSTP, p. V-10)

"Disagreement exists within the scientific community over the significance of airborne sulfates to human health. Some researchers conclude that there is a negligible effect at prevailing concentrations; others have found a significant association—several percent of annual mortality, primarily among people with preexisting cardiac or respiratory problems. By combining the various estimates, this study concludes that a reasonable estimate of the magnitude of health risk posed by current levels of sulfates and other particulates is about 50,000 premature deaths (2 percent of total deaths) per year in the United States and Canada. This estimated health risk from transportation air pollutants is a measure of *possible* harm. It can neither be confirmed nor disproven until further research is conducted.

Acidified waters can dissolve metals and toxic substances from soils, rocks, conduits, and pipes, and subsequently transport them into drinking water systems. Municipal water supplies can be monitored and corrected quite easily; potential problems with well water in rural areas are more difficult to detect and mitigate." (OTA, p. 13)

"No adverse human health effects have been documented as being a consequence of metal mobilization by acidic deposition. On the other hand, interest in the phenomena of acid deposition is recent and few investigations, if any, have been made into the possibility of indirect effects on human health." (CARP II, p. 6-56)

"Potential impacts of acidic deposition on methyl mercury concentrations in freshwater are of great interest for several reasons.

a) Fish and fish products are the major if not the only sources of methyl mercury for humans.
b) Consumers of freshwater fish have a greater possibility of exceeding allowable daily intakes of methyl mercury than do consumers of other forms of fish.

c) Pike and trout, freshwater fish among the most

likely species to be affected by acidic deposition, have the highest user consumption figures and the highest average methyl mercury levels." (CARP II, p. 6-56)

"People receiving drinking water from roof-catchment cistern systems should be considered a potential risk of increased intake of lead in areas of acidic deposition and especially if cisterns that are used have no particulate filters." (CARP II, p. 6-57)

"From the point of view of human health risks, any increases of lead concentrations in drinking water should be viewed as an additional burden of lead. This is especially important where substantial numbers of children already have elevated blood lead levels." (CARP II, p. 6-57)

"Acute or chronic diseases in humans have not been related to normal dietary intake of aluminum from food or drinking water. However, a potential threat exists for patients undergoing hemodialysis if aluminum concentrations in the water used in this treatment exceed 50 µg of aluminum per liter." (CARP II, p. 6-57)

VII. On the basis of current information, what steps should be taken to abate the effects of acid rain?

"The Clean Air Act of 1970 marked the formal recognition by the United States government of the importance of reducing emissions of sulfur and nitrogen oxides to the atmosphere. New power plants constructed since 1970 do control such emissions to lower levels. Such controls were a prudent first step, but have not accomplished all that was initially intended. We recommend that additional steps should be taken now which will result in meaningful reductions in the emissions of sulfur and nitrogen compounds into the atmosphere, beginning with those steps which are most cost-effective in reducing total deposition. Emission reductions are meaningful when they produce a detectable decrease in both acidic deposition and degradation of the biosphere." (OSTP, p. III-1)

"Reducing present SO₂ emissions would reduce depositions of total sulfur, and, consequently, both reduce the probability of major degradation of additional acid-sensitive lakes or forests and allow anthropogenically acidified areas to begin to return to their original condition." (OSTP, p. III-4)

"Four approaches for congressional action on acid deposition and other transported air pollutants are discussed below.

- A. Mandating emissions reductions to further control the sources of transportation pollutants.
- B. Liming lakes and streams to mitigate some of the effects of acid deposition.
- C. Modifying the Federal acid deposition research program to provide more timely guidance for congressional decisions.
- D. Modifying existing sections of the Clean Air Act to enable the Environmental Protection Agency, States, and counties to more effectively address transportation air pollutants other than acid deposition.

Congress could choose to adopt some or all of these approaches in its consideration of clean air legislation. A comprehensive strategy to address transportation air pollutants might well include options from all four of the approaches." (OTA, p. 15)

"Of the options presently available only the control of emissions of sulfur and nitrogen oxides can significantly reduce the rate of deterioration of sensitive freshwater ecosystems. It is desirable to have precipitation with pH values no lower than 4.6 to 4.7 throughout such areas, the value at which rates of degradation are detectable by current survey methods, as mentioned above. In the most seriously affected areas (average precipitation pH of 4.1 to 4.2), this would mean a reduction of 50 percent in deposited hydrogen ions. Control of SO₂ from new electrical generating plants alone would be insufficient to accomplish this, and thus restrictions on older plants must be considered. Furthermore, there are no proposed restrictions on the emission of nitrogen oxides, and the amounts of these substances emitted are expected to continue to increase." (NAS-1, p. 181)

APPENDIX

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Viewpoint

Attachment VIII

Changing perspectives on air-pollution stress

It has been a decade and a half since acid rain began to be considered a problem for regional ecosystems in Europe and North America. As more has been learned about the nature of air pollution and more sophisticated techniques have been developed for measurement, it has become apparent that acid rain is only one of an interrelated array of airshed-watershed problems. Despite important reductions in some pollutant emissions, we believe the situation today is worse than it appeared to be 15 years ago.

Acid rain was the first air pollutant to receive major attention. It was measured as hydrogen ion pollution collected in bulk precipitation collectors, which are continuously open during rain and non-rain periods. Research and debate focused on its effects on bodies of water and on the sensitivity of landscapes. With the discovery of *waldsterben* (dying forest) in Europe and spruce dieback in the United States, further attention shifted to forests. With continuing research, emphasis shifted away from the effects of hydrogen ion and toward other pollutants in precipitation. Recently scientists have reported data, gathered with monitoring techniques not available 15 years ago, showing that in some locations dry deposition of hydrogen ion, sulfur, and nitrogen in coarse and fine particles and vapors may exceed the same substances measured in bulk precipitation.

As scientists learned about acid rain, they also became more aware of photochemical oxidant pollution. What had been considered a local or subregional problem became recognized as a problem for much of the nation. Symptoms of ozone damage on crops and natural vegetation have been found in a majority of states. Substantial reductions in the productivity of crops and trees due to relatively high ambient ozone levels have been measured at rural locations throughout the nation. In some places, photochemical oxidants and acid rain are simultaneously affecting vegetation. In a recent article we and our colleagues reported an acid cloud covering thousands of square kilometers of the eastern United States. The moisture it deposited on vegetation was extremely acid, approximately pH 3, and contained sulfur and nitrogen at concentrations many times those measured in precipitation elsewhere. At one site, the deposition of acid-cloud water was accompanied by ozone concentrations known to cause plant damage. Therefore, the vegetation was simultaneously subjected to two extreme, episodic stresses.

As understanding and measurement ability have increased, estimates of the magnitude and severity of the air pollution problem have grown. The problem has shifted from initial concerns about the long-term cumulative effects of hydrogen ions on ecosystems to current concerns about other pollutant components and interactions of all the pollutants in precipitation. The recent measurements of dry deposition, cloud-water deposition, and photochemical oxidant concentrations have greatly increased estimates of airborne pollutants reaching ecosystems. They have shown that the photochemical oxidant problem cannot be separated from the acid-rain problem and that the combined effects may be both episodic and long-term.

These findings indicate that regional air pollution is more severe than it was naively perceived to be 15 years ago. Solving the problem will be extremely difficult and expensive both in terms of monitoring and assessing effects on ecosystems under realistic conditions. Required reductions in the emission of atmospheric pollutants may be much larger than we originally thought. The longer the delays in setting an official policy of comprehensive correctional measures, the more environmental damage may occur. Extensive damage, in turn, would increase the cost of measures necessary for protection and recovery.

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SCIENTIFIC INTEGRITY IN THE NAPAP INTERIM ASSESSMENT *

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The opportunity to participate in this Technical Amplification of NAPAP's Interim Assessment was especially welcome for two reasons:

1) because of the roles I played earlier in helping bring the National Acid Precipitation Assessment Program (NAPAP) into being; and
2) because of the roles I was asked to play more recently in preparing the Interim Assessment itself. In 1977-78 I joined with three other scientists in writing the original Draft Plan for NAPAP (Galloway et al, 1978). In 1980-81 Dennis Tirpak of EPA and I developed the first organizational plan for NAPAP. Since then I have participated as a research scientist in two Task Groups: Deposition Monitoring and Terrestrial Effects. In 1984-85 I drafted a portion of the materials used by Larry Kulp and his colleague, Jack Winjum, in preparing Chapter 7 -- Effects on Forests. In 1987 I served as an independent reviewer of Chapter 5 -- Acidic Deposition and its Gaseous Precursors; I also assisted the US Forest Service in its technical review of Chapter 7 -- Effects on Forests. Thus, I have both a keen interest in NAPAP and in the scientific integrity of its Interim Assessment.

Purpose: In essence, NAPAP was designed to provide an improved understanding of the phenomenon of acid precipitation and its effects on lakes, streams, fish, crops, forests, materials, visibility, and human health. The original legislation called for periodic reports for use by leaders in the Congress and Executive Branch of our Federal government, state and local governments, industries, and citizens. These reports were to include both an assessment of the state of scientific understanding and recommendations for action by:

- state and federal governments,
- public utilities and transportation industries,
- other industries and state and federal organizations concerned with our natural resources including surface and ground waters, forest resources, agriculture, fisheries, wildlife, tourism, and outdoor recreation, and
- public interest groups and government officials concerned with environmental quality and our diplomatic, economic, and scientific relationships with Canada, Mexico, and other nations of the world.

* Contribution to a panel discussion at the conclusion of an International Conference on Acid Precipitation: A Technical Amplification of NAPAP's Findings. Other panel members included Drs. Volker Mohnen, Allen LeFohn, Hans Martin, James Kraemer, Larry Kulp, former Director of Research for NAPAP, and Sagar Krupa, Moderator. The Conference was sponsored by the Air Pollution Control Association at the Pittsburgh-Hilton Hotel in Pittsburgh, Pennsylvania on January 26-28, 1988.

Financial Support: NAPAP has enjoyed substantial financial support over an extended period of years. Expenditures grew from an initial \$18,000,000 per year in 1982 to \$85,000,000 per year in 1985-87. From its inception, NAPAP also enjoyed a high degree of public interest by the citizens and industries of our country -- not only because their taxes made the program possible, but also because the scientific findings and assessments provided by NAPAP will be important in making future decisions about management of both the economic systems and the quality of our environment in North America.

Every scientist and program manager in NAPAP has a responsibility to do his or her part to insure that this substantial investment of public funds results in an equally substantial and scientifically sound return on the public's investment. The scientist's duty in a democracy, is to develop the scientific foundation for informed decisions by leaders of industry, government, and other organizations in our society (Kantrowitz, 1975).

Scientific Integrity: In programs of publicly-supported scientific research and assessment, scientific integrity is a joint responsibility of scientists and program managers. Scientists are responsible to design and perform the experiments, make the measurements, interpret the results, and publish both scientific findings and implications for management that derive from these findings and from evidence in previously published scientific literature. Managers are responsible to be sure that the general and specific objectives of the program are met. This involves providing the financial and other resources that are necessary to get the job done, coordinating the activities of the various teams of scientists, providing counsel and advice about quality control and data management, and insuring that a high-quality synthesis and integration of research program findings and previously published findings is achieved on time.

Congratulations: Larry Kulp and his staff deserve a vote of thanks for finally getting this first Interim Assessment completed. Acid precipitation is a complex phenomenon and its effects are no less so. It was a formidable task to complete the drafting, reviewing, repeated rewriting, and editing of this Interim Assessment. At last, the document is available for public review, comment, and both scientific and public decision making.

Dr. LeFohn, his Technical Program Committee, and other leaders of the Air Pollution Control Association (APCA) also deserve our thanks for arranging this Technical Amplification of NAPAP's Interim Assessment. Whether intentionally or not they acted in accord with a procedure recommended some years ago by Van Rensselaer Potter (1976):

"...the following procedure [is recommended] as a reflection of the ethics of science:

When contact between an individual scientist and the press or a policy-making body seems called-for with respect to a complex social issue, the appropriate procedure for the individual will be 1) deliberately to seek out competent peers

who hold different points of view as to the social significance and/or scientific validity of the new findings 2) to request arrangements for the participation of one or more such individuals in any public presentation and 3) to seek the formulation of a consensus.

Each scientific society or association should attempt to help their individual members by facilitating suitable arrangements for the above process, for example, at national meetings."

Discrepancies Between the Scientific Chapters and the Executive Summary of the NAPAP Interim Assessment: Many of the important public and scientific reservations about the NAPAP Interim Assessment are a consequence of disparities both in tone and in substance between the 10 scientific chapters in Volumes II, III, and IV and the major conclusions of the Executive Summary in Volume I. In the formal and informal discussions at this meeting, it has become clear that many of these disparities came about because very different procedures were used in drafting and reviewing the scientific chapters and the Executive Summary. Unfortunately, these important differences are not revealed in the document itself.

Some information about the processes of drafting and reviewing the Interim Assessment is contained in the Acknowledgements sections of each scientific chapter and the Preface of the Executive Summary. Responsibility for the accuracy and completeness of each scientific chapter is clearly indicated. The first line of responsibility is the Principal Author or authors of each chapter; the second is the series of "independent reviews" which were provided by scientists whose names are given in the Acknowledgements section of each chapter; and the third is "comments on drafts" of each chapter "provided by various Federal agencies on the basis of their own internal and external reviews."

By contrast, the Executive Summary contains no Acknowledgement section, shows no Principal Author, mentions no "independent reviews", and makes no reference to the roles played by the Director of NAPAP, the members of the Interagency Science Committee, Interagency Policy Committee, Interagency Task Force on Acid Precipitation, or other leaders within the 12 Federal agencies listed on the inside cover and title pages of the document. The Preface of the Executive Summary does make some mention of drafting and review processes but the procedures mentioned pertain only to the scientific chapters and not to the Executive Summary:

"As a whole, the primary role of this document is to critically evaluate, synthesize, and present state-of-the-science information in order to provide a sound basis for the formulation of public policy as it pertains to the issue of acidic deposition. Drafts of each chapter of this document have been critically reviewed by a panel of three to eight independent experts (peer reviewers)."

After extensive discussions with Larry Kulp and the members of the Interagency Science Committee present at this APCA Conference, it appears that a more complete statement would have read as follows:

"Drafts of each scientific chapter in Volumes II, III, and IV have been critically reviewed by a panel of three to eight independent scientific peer reviewers selected from a variety of university, industry, government, and private consulting organizations. These reviewers included many scientists and a few research managers in the Federal agencies involved in NAPAP.

A different procedure was used in developing the Executive Summary. In this case, the general conclusions were drafted by the Director of Research for NAPAP. Portions of the major conclusions in the Executive Summary were taken from the peer reviewed state-of-science described in Volumes II, III, and IV, but the final wording and interpretations in the Executive Summary were determined in negotiations between the Director of Research and a group of senior scientists and research managers from the Federal agencies supporting NAPAP."

In other words, the scientific chapters in this Interim Assessment are a product of essentially the same kind of peer-review processes used throughout the world in producing high-quality scientific publications. By contrast, the Executive Summary is, in essence, a Federal agency perspective on the phenomenon and effects of acid deposition. Obviously, such perspectives have their place in public decision making, but they should be clearly labeled as such. The Executive Summary of any document should not be given the appearance of being a product of scientific peer-review processes unless the Summary itself was reviewed by competent scientific peers.

Recommendations for Future NAPAP Assessments: Two recommendations for the future appear to be called for:

- 1) A complete description should be given of the procedures actually used in drafting and reviewing all scientific chapters and the Executive Summary of future NAPAP assessments; and
- 2) Individual scientists and groups of scientists in NAPAP's various Task Groups should take a larger measure of responsibility for the scientific integrity of future assessments.

The first recommendation is essential to the maintenance of public confidence in any publicly supported scientific research and assessment activity. In a democracy, the public has a right to know both the people involved and the procedures used to insure the integrity of both interim and final program reports.

The second recommendation will require some additional initiative on the part of scientists within the NAPAP program. One method by which this could be achieved would be to encourage individual scientists and groups of scientists within NAPAP to identify specific areas of science in which they have special competence. While preparing their usual NAPAP progress reports and scientific papers, each scientist or group should also formulate one or more summary statements of conclusion deriving from their own research and that of

others both within and outside of NAPAP. Each summary statement should be accompanied by references to the specific published (or as yet unpublished) scientific evidence on which the statement is based. Each statement should then be submitted for review by at least two scientific peer reviewers selected by the author(s) or their program managers. If these reviewers concur that a given statement is scientifically sound, they should indicate their concurrence by submitting a signed statement indicating that they:

- 1) have examined both the statement and the evidence on which it is based;
- 2) concur that the statement is "consistent with all available scientific evidence and not contradicted by any important scientific evidence"; and
- 3) find the statement worthy of consideration in connection with the annual or other periodic reports of NAPAP.

Approved statements, references, and signed notices of concurrence should be submitted for such additional review as the program managers consider desirable. Statements containing a consensus of informed scientific judgment should then be considered for incorporation in the Annual, Interim, or other reports of NAPAP. These reports should attempt to develop as complete a statement of scientific consensus as available evidence will permit. Footnotes or other references could be used to recognize scientists whose summary statements were especially valuable in formulating the principal findings of the NAPAP research and assessment program.

Recommendations For Future Research on Forests: Decreasing present uncertainty about the effects of acid deposition and other airborne chemicals on forests is one of the most important challenges facing NAPAP. NAPAP's principal effort in this connection is the Forest Response Program which finally became operational only two years ago -- in 1986.

Four recommendations appear to be essential if the Forest Response Program is to provide the quality information that will be needed to help resolve present uncertainties about effects on forests.

- 1) The Forest Response Program will need to be sustained for at least 5 to 10 years beyond the presently scheduled end of NAPAP in 1990.
- 2) Greater emphasis will need to be placed on rigorous methods by which to distinguish the individual and combined effects of the seven different types of stress factors that affect the growth and stability of forests: natural competitive stresses, natural climate stresses, natural chemical stresses, natural biological stresses, human disturbance stresses, airborne chemical stresses, and global climate stresses.

The logical methods for determining cause-and-effect dictate that a causal relationship can be inferred only when there is a strong pattern of consistency, responsiveness, and/or a proven biological mechanism with the suspected causal factors. In air pollution research with forest trees this means that:

a) a strong pattern of spatial and/or temporal consistency must be found between dysfunction in the forest and the presence of one or more specific airborne chemicals;

b) a clear relationship must be found between dose of airborne chemical(s) and response of forest trees; and

c) a proven biological mechanism or a series of stepwise biological processes must be found by which dysfunction in forest trees can be linked to one or more specific airborne chemicals.

In simple systems that involve only one or two causal factors, any two of these "three patterns of linkage" may be sufficient to infer cause. In more complicated systems, all three may be necessary.

3) More effective communication and coordination will need to be developed between the atmospheric and biological scientists within the Forest Response Program. These improvements will be especially important in evaluating the first two of the "three patterns of linkage" described above.

4) Greater emphasis will need to be placed on determining the nature and magnitude of effects on whole forests even if effects of airborne chemicals on individual trees within one or more species of trees are proven. The following questions are of special significance in this connection:

a) How much injury to how many individual trees will it take to cause a significant decrease in the productivity of whole forest stands;

b) How do airborne chemicals affect the genetic diversity within species of forest trees; and

c) How do airborne chemicals affect the species composition of mixed-species forests and the age-class structure of uneven-aged forests?

For further discussion of most of these recommendations, see Woodman and Cowling (1987).

Summary: NAPAP was designed to provide an improved understanding of the phenomenon of acid precipitation and its effects on lakes, streams, fish, crops, forests, materials, visibility, and human health. The program has enjoyed substantial financial support over an extended period of years. Every scientist and program manager in NAPAP has a responsibility to do his or her part to insure that this substantial investment of public funds results in an equally substantial and scientifically sound return on the public's investment. Many of the important public and scientific reservations about the recently released NAPAP Interim Assessment are a consequence of disparities both in tone and in substance between the 10 scientific chapters in Volumes II, III, and IV and the major conclusions of the Executive Summary in Volume I. Two recommendations appear to be called for in maintaining both public and scientific confidence in future NAPAP assessments:

1) A complete description should be given of the procedures actually used in drafting and reviewing all scientific chapters and the Executive Summary; and

2) Individual scientists and groups of scientists in NAPAP's various Task Groups should take a larger measure of responsibility for the scientific integrity of future assessments.

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Mr. SCHEUER. Thank you, Dr. Likens. I've got to answer this roll call vote, which is going to take a few minutes.

[Brief recess.]

Mr. SCHEUER. Okay. We have two more witnesses, and we're really running late. So, I'm going to ask the last two witnesses—it's now nine minutes of—to try and take five or six minutes, no more, to summarize their testimony, and perhaps discuss their views on the testimony that you heard from Dr. Mahoney and perhaps this extraordinary article on the front page of the Washington Post on the U.S. negotiators in Geneva suggesting, or demanding, a right on the part of the United States to increase some key ingredients of acid rain, a whopping 20 percent.

So, if you have any thoughts on that or on Dr. Mahoney's testimony, I'd welcome that.

All right. Dr. Galloway, why don't you take your five or six minutes, and then we'll go to Mr. Goffman.

Dr. GALLOWAY. Thank you, Congressman.

Mr. SCHEUER. And, of course, your full statement will be printed in the record.

Dr. GALLOWAY. Yes, I appreciate that.

Thank you, Mr. Chairman. The purpose of today's hearing is to address the NAPAP 1985 assessment. I have several comments. They're outlined in my testimony.

I will, for the sake of time, condense my remarks to considering the state of knowledge about the acidification of surface waters in the southeastern United States.

The NAPAP 1985 assessment stated there are no streams in the southern Blue Ridge province less than pH 6.0. Therefore, there are no sensitive streams, in the area of the southeastern United States that they looked at, sensitive to acidification.

Does this mean that there are in reality no sensitive streams? No, it does not.

The 1985 NAPAP assessment ignored a published study showing that the streams in Shenandoah National Park are extremely sensitive to acidification. I presented this material in testimony before a Senate Subcommittee a year and a half ago, well in advance of the '85 assessment, and this was not contained in the '85 assessment.

However, even if NAPAP did not address this issue or listen to these published facts, the Commonwealth of Virginia did. They supported a study to investigate over 400 of the native brook trout streams in the Commonwealth of Virginia.

There are 450 identified native brook trout streams in the Commonwealth. My group has analyzed over 80 percent of these.

The distribution of these streams is shown in the first figure attached to my testimony. They range all up and down the mountainous portions of the Commonwealth of Virginia. The conclusions from this study are as follows:

78 percent of the sampled streams have alkalinity values less than 100 microequivalents per liter, making them sensitive to acidification;

49 percent, about half, have alkalinity values less than 50, making them very sensitive to acidification;

11 percent have alkalinities less than 0, meaning that they are now acidic, and have probably become acidic in the last 10 years; and

18 percent of the streams had pH values less than 6.

It's very fortunate the Commonwealth of Virginia undertook this study, for if we had relied on the NAPAP investigation, from their pilot stream study we would not have known this.

And, indeed, after seeing a draft version of the entire stream study from NAPAP, that study does not agree with the study of the Commonwealth of Virginia. The Commonwealth of Virginia has identified a much higher percentage of streams sensitive to acid deposition.

It's not only Virginia that's of concern here. It's also other states with similar soils and geology and vegetation, including North Carolina, South Carolina, Tennessee, Kentucky, and Maryland.

After six years of research under NAPAP, is it true that, quote, we don't know, unquote? Is it true that there still exists a very large amount of scientific uncertainty, so large an amount that the official position of this Administration is to take no action on the acid deposition issue?

The Executive Summary of the 1985 assessment of NAPAP implies that it is true that we don't know, that there's a large amount of scientific uncertainty.

That is a misrepresentation of the state of science. There have been four volumes published by the National Academy of Sciences stating the impacts of acid deposition on aquatic ecosystems.

We do know that acid deposition acidifies aquatic ecosystems. We do know that they are of large extent, and not only in the northeastern United States but the southeastern United States as well. We do know that there are large segments of the biological populations at risk.

It's my belief that the scientific community has essentially done its job, and has accumulated enough information about aquatic ecosystems for the policymakers to stop the discussion about whether to reduce the emissions of sulfur and nitrogen and to begin the discussion of how to reduce them.

Thank you very much.

[The prepared statement of Dr. James Galloway follows:]

TESTIMONY OF JAMES N. GALLOWAY

Professor, Environmental Sciences Department

University of Virginia

to the

Subcommittee on Natural Resources, Agricultural Research,
and Environment

of the

Committee on Science, Space and Technology

U. S. House of Representatives, Washington, D. C.

Wednesday, April 27, 1988

INTRODUCTION

I am a Professor of Environmental Sciences at the University of Virginia. I have been investigating the phenomena and effects of acid deposition for the past thirteen years and have published over sixty peer-reviewed papers on topics of long-range transport of acids, temporal and spatial trends in acid precipitation and the impacts of acid deposition on aquatic and terrestrial ecosystems. This research has been performed in North America, Australia, Asia, Europe, Africa and South America. Based on these experiences, I'd like to discuss several aspects of the acid deposition issue.

The purpose of this hearing is to examine the status, management and progress of research carried out under the auspices of the National Acid Precipitation Assessment Program [NAPAP]. My specific contribution to this hearing will be to examine the state of scientific uncertainty that exists on the phenomena and effects of acid deposition in light of the recent 1985 NAPAP assessment.

The position of the current administration on the acid deposition issue is that the degree of 'scientific uncertainty' on the phenomena and effects of acid deposition is too great to formulate an emissions control program for sulfur and nitrogen oxides. The 'scientific uncertainty' policy was recently articulated by the US Department of State at the Tenth Sokol Conference on International Law as a reason to delay negotiations on the reductions of the transport of sulfur and nitrogen oxides to Canada. One of the justifications for the 'scientific uncertainty' principle was the recent NAPAP 1985 assessment report.

The posture of 'scientific uncertainty' is a convenient one, but is it correct? What exactly are the uncertainties? Does the general scientific community agree with the NAPAP about the extent and magnitude of the uncertainties? Are there no areas of consensus? In this testimony, I will list the critical questions on the acid deposition issue and assess our degree of consensus.

ACID DEPOSITION: THE ATMOSPHERE

The critical questions pertaining to the atmospheric dynamics of the acid deposition problem concern the amount of natural vs. anthropogenic sulfur and nitrogen emitted to the atmosphere, the degree of transport, the types of transformation reactions as they impact the effects of acid deposition and whether reductions in emissions will be matched by reductions in deposition. There is scientific consensus on the following points:

- The human emission of S and N to the atmosphere of the United States overwhelms the natural atmospheric emissions.
- Significant atmospheric transport of S and N compounds can occur on scales of hundreds to thousands of kilometers. In this context, the word 'significant' means that long-range transport can be the major ecosystem source of S and N deposited from the atmosphere.
- The atmospheric deposition of sulfur and nitrogen has increased by over 1000% in eastern North America due to anthropogenic activities.
- If the emissions of S to the atmosphere are decreased, there is a corresponding decrease in the deposition of S from the atmosphere. This is important for it means that control of S and N emissions will result in less impacted atmospheric deposition.

In summary, the degree of 'scientific uncertainty' is very slight in the above statements. Our knowledge for the atmosphere is relatively complete. We know there are higher concentrations of acidifying compounds, we know that they can be transported long distances, we know that there are higher deposition rates and that reductions in emissions cause reductions in depositions.

One area where there are larger uncertainties is that of chemical transformations in the atmosphere--how fast are the reactions occurring? What are the reactions mechanisms? While these are interesting scientific questions, they have little relationship to the issue of the effects of environmental acidification. The impact of S and N deposition on aquatic and terrestrial ecosystems is almost completely independent of the type of sulfur or nitrogen deposited. Thus the uncertainties in our knowledge of the atmospheric chemistry of the sulfur and nitrogen has little bearing on the question at hand--how much does the increased atmospheric deposition of sulfur and nitrogen impact aquatic and terrestrial ecosystems?

ACID DEPOSITION: EFFECTS ON AQUATIC ECOSYSTEMS

Review of Scientific Consensus:

The critical questions concerning the impacts of acid deposition on aquatic ecosystems are as follows: Where are the sensitive aquatic ecosystems located?, What is their extent?, Have they been acidified?, Has there been damage to biological populations?, Will there be continued acidification?, If sulfur

and nitrogen deposition decreases, will aquatic ecosystems recover? These questions are easy to answer for the effects of acid deposition on surface waters are the least controversial.

- There are thousands of lakes and streams that are sensitive to acidification in all of the continents of the world. In North America, a large number of these sensitive systems are downwind of the major source regions of sulfur and nitrogen oxides.
- In North America and Europe, a large number of these lakes and streams have been acidified.
- Even if the rate of acid deposition does not increase there are thousands of streams that will be acidified due to the phenomena of delayed acidification.
- Slight increases in the acidity of sensitive aquatic ecosystems will cause biological effects.
- A reduction in acid deposition will result in an eventual recovery of the natural chemical composition of surface waters. Ecological recovery will take substantially longer.
- In some areas [all affected surface waters south of Penn.], the chemical and biological recovery will take decades, if it occurs at all.

These statements represent consensus views from the body of the scientific literature. These views are not new, for the most part they have been present in every credible review of the acid deposition issue over the past five years. By way of example of 'credible reviews', I cite the four reports that the U. S. National Academy of Sciences has published on the acid deposition issue [NRC, 1981; NRC, 1983; NRC, 1984; NRC, 1986].

New Findings

I first began testifying to Congressional committees on the acid deposition issue in 1976. Since that time, the basic messages on the effects of acid deposition as stated above have been confirmed by countless studies. In some instances the situation is worse than was initially supposed.

A case in point is the acidification of streams in the southeastern United States. For a number of years, research on the impacts of acid deposition on aquatic ecosystems has been focused on the northeastern United States due to the occurrence of regional scale sensitivity and acidification. However, the southeastern United States receives deposition that is as acidic as the northeastern United States and has surface waters that are as sensitive. The southeastern waters have not acidified to the degree that the aquatic ecosystems in the northeastern United States have, due to the ability of the soils to temporarily store the acidic material. Unfortunately, this storage potential is finite and as has been presented before the U. S. Senate Committee on Environment and Public Works in October 1986 and briefly mentioned in the 1985 NAPAP assesement, this storage capacity is being saturated and regional scale acidification of sensitive surface waters has the potential to occur.

How extensive are the sensitive aquatic ecosystems of the southeastern United States? Are they acidifying? Will they acidify to the extent that biological damage results?

The answers to these questions are not available for the entire southeastern United States, however, one state, Virginia, has performed a study [the Virginia Trout Stream Sensitivity Study (VTSSS)] to determine the extent of aquatic ecosystems sensitive to acidification by acid deposition. The results of the first phase of this study are as follows.

The VTSSS was initiated to determine the sensitivity to acidification of the streams hosting the indigenous eastern brook trout (*salvelinus fontinalis*) in the mountainous region of Virginia. The project was managed by Mr. Rick Webb and directed by Dr. George Hornberger and myself of the Department of Environmental Sciences, University of Virginia. During the period of April 24 to May 4, 1987, 80% of the total number [450] of identified streams with naturally reproducing trout populations in Virginia were sampled to determine their sensitivity to acid deposition (Figure 1).

Sample analyses include alkalinity, pH, conductivity, calcium, magnesium, potassium, sulfate, nitrate, chloride, and silica using similar protocols as used by NAPAP in their study of streams. Initial evaluation of sensitivity has been based on alkalinity--with 100 ueq alkalinity/l taken as a threshold value above which chronic streamwater acidification is unlikely to occur at current levels of acid deposition. The findings of the study are:

- Seventy eight percent of the sampled streams have alkalinity values less than 100 ueq/l, making them sensitive to acidification by acid deposition (Figure 2).
- Forty nine percent have alkalinity values less than 50 ueq/l, making them very sensitive to acidification (Figure 2).
- Eleven percent have alkalinity values less than 0 ueq/l, meaning that they were acidic (Figure 3).
- Eighteen percent of the streams had pH values < 6.0.
- Based on model predictions and measurements obtained for other streams, these sensitive streams have been acidified to some degree and will continue to acidify in the future.
- The regional scale impacts of acid deposition will be at least as extensive in the SEUS as it is today in the NEUS. The time scale of this acidification is on the order of 10-20 years. This delayed acidification is due to the nature of the SE soils. However, even though the acidification is delayed, it is inevitable.

These results indicate that most of the state's wild trout streams are sensitive to acidification by acid deposition and that they will acidify in the future. A long-term trend monitoring program of 65 sites has been initiated to determine the actual

amount of acidification that is presently occurring.

These findings for the Commonwealth of Virginia are different from those reported by the NAPAP in its 1985 assessment. The differences result from a difference in study design and an inefficient review of the scientific literature by NAPAP.

The Executive Summary of the NAPAP report cites a survey of 54 small streams in the Southern Blue Ridge Province to conclude that none of the streams had pH < 6.0 even though the region receives moderate to high levels of acid deposition. The reason they found no sensitive streams is that their sampling design was biased against the low alkalinity streams. However, even with this bias, they should have reviewed the literature effectively. If they had, they would have found a 1985 publication that shows the results of a synoptic survey of 56 streams in Shenandoah National Park, Virginia [Lynch and Dise, 1985]. They not only found that 10 out of 56 of the streams had flow weighted pH values < 6.0 but that all the watersheds showed signs of acidification by atmospheric deposition. Thus, the results implied for the SEUS by the 1985 assessment are, at best, misleading.

FOCUS FOR THE FUTURE

The degree of scientific uncertainty about many aspects of the acid deposition issue is low. For the atmospheric phenomena of acid deposition and the effects on aquatic ecosystems, there is general scientific consensus. In fact, when new knowledge is added, it increases the extent of the impacts of acid deposition on the environment. A case in point is the recently released study on the impacts on nitrogen oxides on the coastal waters of eastern North America.

It is my belief that the scientific community has accumulated enough information for the policy makers to stop the discussion about whether to reduce emissions of sulfur and nitrogen, and to begin the discussion of how to reduce them.

Critical questions that remain for the future primarily revolve around the forested ecosystem. These questions will not have easy answers that are available in the short term. A continuing, long-term commitment by the Federal Government is required to determine the extent of terrestrial changes induced by the combustion of fossil fuels.

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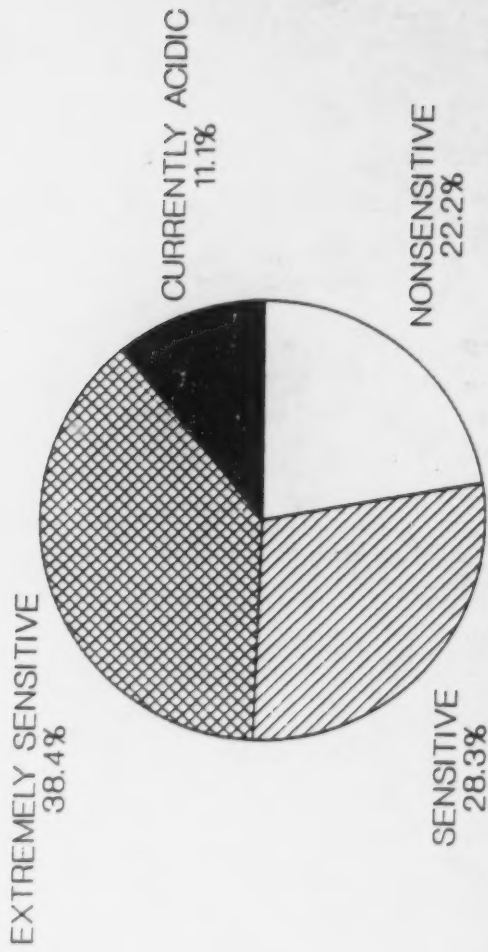
FIGURE 1

DISTRIBUTION OF NATIVE BROOK TROUT
STREAMS IN VIRGINIA



SENSITIVITY OF NATIVE TROUT STREAMS TO ACIDIFICATION BY ACID DEPOSITION

FIGURE 2



SPRING 1987 SURVEY OF 363 STREAMS
VIRGINIA TROUT STREAM SENSITIVITY STUDY

FIGURE 3

VIRGINIA TROUT STREAM SENSITIVITY STUDY

DISTRIBUTION OF ACIDIC
NATIVE BROOK TROUT STREAMS



Mr. SCHEUER. Thank you very much, Dr. Galloway. Mr. Goffman?

Mr. GOFFMAN. Thank you, Mr. Chairman. I will try to summarize my summary, if you will, in the interest of time.

I am an attorney on the staff of the Environmental Defense Fund, where I work very closely with my senior colleague, Dr. Michael Oppenheimer, a distinguished atmospheric physicist and an expert on acid deposition and its ecological impacts.

Dr. Oppenheimer has reviewed the NAPAP assessment carefully and assisted in the preparation of my testimony, particularly the written testimony.

At the risk of being repetitious, I'd like to focus on the Executive Summary of the Interim Assessment released last fall, because it has had, and it's bound to have, a disproportionate impact on public debate and policy decision making with regard to acid rain control.

That doesn't mean that I've been deaf this morning to the rather constructive suggestions that Dr. Mahoney has made about how the balance of the program should proceed. And I think the opening up of the assessment process will give us a chance at least to cure some of the downright abuses that we saw in the Executive Summary of last fall.

Rather than go through all of the problems that we have with the Executive Summary, let me just pull out one example that suggests that the Executive Summary was not only an inaccurate and distorting document but that it was, in fact, intentionally suborning a preconceived do-nothing or no-action agenda, and was not distilling or summarizing scientific findings.

In my view at least, the most revealing part of the Executive Summary was its treatment of the ground level ozone problem. In order to demonstrate that sulfur dioxide and oxides of nitrogen are not responsible for observed crop and forest damage, the assessment argued strenuously—I should say the Executive Summary argued strenuously—that ground level regional ozone is the one true culprit of any damage that there is to forests and crops.

First of all, this either/or approach to individual pollutants is, as Dr. Likens testified, contradicted by the underlying scientific research that is part of the NAPAP program itself.

But, more significantly, despite the Executive Summary's own arguments that ozone is the problem, the summary studiously managed to avoid concluding that ozone should be controlled, even though that is the unavoidable logic of its own position.

Instead, the assessment, or the Executive Summary, dropped its cloak of scientific analysis and made a blatant policy judgment, stating that controlling the precursors of ozone would be either too expensive or technologically infeasible. Yet, even in that assertion—

Mr. SCHEUER. Excuse me, I didn't hear that. Could you go back a sentence and pull the mike closer, and see if you can't speak right into the mike.

Mr. GOFFMAN. Sure. I'm sorry.

Instead of accepting the logical inevitability that, if regional ozone is the culprit causing crop and forest damage and concluding as logic would dictate that the real answer here is to control ozone,

the assessment or the Executive Summary discounted that possibility.

And, stepping back, or stepping away from its obligation to give a scientific assessment, it made a policy judgment very blatantly, and said, we just can't afford or we don't have the technological wherewithal to control the precursors of ozone.

And even that assertion is not true. It's belied by the evidence that's readily available about the availability of ozone precursor control technology and the affordability of that technology. It's being used here in the States. It's being used in Japan. It's being used in Western Europe.

So, there's a dual problem there. The assessment or the Executive Summary abandoned its role of providing a summary of scientific assessment and went right after policy judgments.

And, having done that, it made a bad policy judgment. And I think that is typical of the problem that the Executive Summary presents to the public debate on what we should do about controlling acid rain.

Again, I think that some of the comments that Dr. Mahoney made were very encouraging, because I think he's going to give the broader scientific and policy-making community a bigger role in the next round of assessments that are being undertaken.

Mr. SCHEUER. Well, specifically, I think he indicated that the Interagency Scientific Committee, which was supposed to not only review it but give it peer review, would be playing that kind of function. I agree with you. I was encouraged, too.

Mr. GOFFMAN. But, you know, those of us who were very concerned about the issue have to be particularly vigilant and make sure that we take full advantage of that opportunity.

Mr. SCHEUER. Go ahead.

Mr. GOFFMAN. The other point that I want to make, and this is to introduce a new factor that I don't even think NAPAP considered, is that a couple of days ago my scientific colleagues at the Environmental Defense Fund released what is perhaps a breakthrough study. It culminated two years of research on the role of acid deposition in the pollution of coastal waters.

What my colleagues concluded is that acid rain is one of the chief sources of excessive nitrogen loadings in coastal waters and estuaries in the east. Thus, by stimulating the overgrowth of oxygen-hoarding algae, airborne nitric deposition, a constituent of acid rain, is contributing to the choking off of our coastal marine habitats, which are the very nurseries of our oceans.

Now, this is an issue that I don't believe the NAPAP study has considered at all to date. And it's particularly ironic that two days after the release of the study the U.S. negotiating position in Geneva is to ask for an increase in the nitrogen constituents of acid rain emissions or acid rain precursors.

Frankly, I think that makes the diplomatic position that was reported this morning in the Post almost absurd.

[The prepared statement of Mr. Joseph Goffman follows:]

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TESTIMONY OF

JOSEPH GOFFMAN, STAFF ATTORNEY

ENVIRONMENTAL DEFENSE FUND

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES,

AGRICULTURE RESEARCH AND ENVIRONMENT

COMMITTEE ON SCIENCE, SPACE and TECHNOLOGY

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APRIL 27, 1988

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INTRODUCTION

On behalf of the Environmental Defense Fund, I would like to thank the Subcommittee for the opportunity to share our views on the National Acid Precipitation Assessment Program. My name is Joseph Goffman. I am an attorney on the staff of the Environmental Defense Fund, a national scientific, economic and legal non-profit organization dedicated to advocating policies to protect human health and the environment. I work closely with Dr. Michael Oppenheimer, a distinguished atmospheric physicist and the chair of EDF's Atmospheric Program. My oral and written testimony is informed by the analysis of Dr. Oppenheimer, one of whose areas of expertise is the problem of acid deposition.

In my testimony, I will focus largely on the Interim Assessment released by NAPAP in September, 1987. Though there are improvements to the Program that we may suggest, the Interim Assessment itself, and its likely, if not intended, impact on the public debate on acid rain control, represent far and away the biggest problems of the Program.

The assessment is riddled with omissions, distortions and misleadingly selective presentations of the underlying scientific research upon which the assessment purports to rely. Not only does the assessment threaten to undermine urgently needed efforts to reduce the air pollutants that lead to acid deposition, but it threatens to discredit the sound scientific research conducted under the auspices of NAPAP.

The assessment puts forward the following argument: 1) the scope of damage caused by acid precipitation is highly limited, and any changes that may occur will happen only very gradually; 2) if there is crop and forest damage related to air pollution then the problem is caused by regional groundlevel ozone; 3) changes in pollutant emissions levels, particularly in the case of SO_2 , will be exceedingly slow, if they take place at all; and 4) in view of this, there is little risk in waiting for the deployment of newly developed "clean coal" technology.

Each of these propositions rests on a factual inaccuracy or distortion and strongly suggests that the Interim Assessment -- as distinct from the underlying scientific research and analysis -- suborned a pre-conceived "no-action" agenda.

I. The Extent of Damage

First, the ecological damage linked to acid deposition is far broader than the assessment acknowledges. The assessment's assertion that acid-related damage to lakes is limited is based on the faulty assumption that only those lakes with a pH value of

5 are of concern. In fact, in an article published in Science magazine in 1985, Schindler et al. demonstrated that the aquatic food chain is disrupted when pH drops below 6. While the assessment may be correct in asserting that 10% of Adirondack lakes are at pH = 5 or below (a fact which should be of great concern in and of itself), 27% of Adirondack lakes are at pH = 6 or below. Moreover, the Environmental Protection Agency's study "Characteristics of Lakes in the Eastern U.S." found that a total of more than 3,000 lakes have alkalinity levels so low as to evince serious perturbation by acid rain.

The assessment concludes that "abrupt" changes in U.S. forests are unlikely, noting only the "possible exception" of some high altitude forests. In fact, a document prepared by EPA staff and submitted to the Administrator in February, 1987 stated:

Mortality, loss of foliage, and reductions in growth rate of red spruce in high-elevation forests in the northern and southern Appalachian regions have increased significantly since the late 1950's and early 1960's. These changes appear to have occurred abruptly within a relatively short time span over a wide geographic range.

The sudden, drastic increase in mortality of Central European forests, which has occurred over a period of less than two decades, parallels the EPA staff's observations and suggests that a "wait and see" strategy would only give way to disaster.

At one point, to support its position that there is no evidence that acid deposition harms forests, the assessment notes the paucity of experiments involving acid fogs with pH values below 3.5 which have been conducted. In another study, however, the EPA has already concluded that acid rains and fogs with pH values at the low end of the 3.0 to 3.5 range cause damage to crops and trees. During summer seasons rains and fogs with pH values in this range occur, particularly in conjunction with the presence of high ozone levels -- and it is during acute deposition episodes such as these that serious biotic damage is probably inflicted.

To further its argument that little drastic change in lakes can be expected to occur, the assessment adopts the "steady state" hypothesis, at least as applied to glaciated lakes (which excludes thousands of lakes in the eastern U.S., since no lakes south of Pennsylvania are glaciated). However, in the September 3, 1987 issue of Nature magazine, P.J. Dillon et al. of the Ontario Ministry of the Environment reported the results of their study of Plastic Lake ongoing since 1979. They observed a continuous increase in the consequences of acidification from

1979 to 1985, even though decreases in acid deposition occurred during that period. The researcher also concluded that the conditions in Plastic Lake are "typical of many thousands of lakes in eastern North America that are sensitive to acidic deposition." The continued deterioration of Plastic lake would not have occurred if the lake were in "steady state" conditions. In addition, a significant array of other scientific evidence flatly contradicts the "steady state" hypothesis, while demonstrating the continued deterioration of lakes affected by acid deposition.

II. The Ozone Problem

The assessment's second major premise, concerning the role of ozone in causing damage to crops and forests, is problematic in two different ways. By attempting to isolate ozone from other atmospheric chemicals in order to suggest that ozone alone, as opposed to SO_2 - and NO_x -produced acid deposition, causes forest damage, the assessment ignores the fact that a number of atmospheric pollutants, including acid rain, cause such damage to foliage. At the same time, the assessment ignores the synergistically destructive effects of pollutants acting in combination, again including acid rain. In addition, despite its insistence on the unique role of ozone in damaging forests and crops, the assessment never once suggests that measures should be taken to control the precursors of ozone.

The assessment's conclusion that observable damage to forests is uniquely caused by ozone exposure is belied by the underlying scientific research reported as part of the assessment. That research concludes that it is not possible to isolate a single pollutant from among the several that contribute to the atmospheric chemistry associated with forest damage and identify that one pollutant or its atmospheric product as the sole cause of such damage. In addition, recent studies by Likens and Boorman concluded that forest damage results from a combination of atmospheric factors, often acting together and including both ozone and SO_2 - and NO_x -bred acid deposition.

Notwithstanding its error in attempting to emphasize the role of ozone, the assessment makes a very strong case for controlling the precursors of ozone. Unfortunately, the assessment assiduously ignores its own logic and fails even to suggest that the precursors of ozone ought to be controlled. Specifically, the assessment concludes that the ozone linked to forest and crop damage results from the presence of naturally and anthropogenically produced volatile organic compounds and man-made NO_x . Instead of concluding that man-made NO_x ought to be controlled (or, for that matter, suggesting that ozone damage is not significant), the assessment simply dismisses the

possibility of reducing NO_x emissions as "too expensive" and not feasible for automobile NO_x emissions.

This blatant policy judgment, too, is ill-founded. In order to control NO_x emissions West Germany has mandated the retrofitting of selective catalytic reduction technology on major stationary sources and Japan has mandated such technology on all new sources. At the same time, California has set an extremely low NO_x emissions standard for automobiles in the state.

The assessment's treatment of ozone by itself strongly suggests a pre-conceived "do-nothing" agenda. By straining against scientific evidence to the contrary to set up ozone as the unique cause of forest damage, the assessment attempts to deny the need for action to control acid deposition. Then, only by defying the logic of its own arguments and disregarding the feasibility of NO_x controls, does the assessment manage to avoid proposing that steps be taken to control ozone.

III. The Emissions Projections

The third element of the assessment's position, concerning the expected change in SO₂ emissions is also unfounded. The assessment relies on projections showing that SO₂ emissions will remain at approximately current levels well into the next century. These projections rest, however, on highly unlikely, if not erroneous, assumptions.

First, the projections assume that all currently operating utility plants will be retired when they reach age 50 (at which time they would be replaced, if at all, by much "cleaner" plants). This assumption is not even shared by the EPA, which assumes a retirement age of 60. Moreover, plants built in the 1960's are being operated and maintained by utility companies in a manner that strongly suggests that the companies intend to operate these facilities indefinitely and certainly well past the age of 50. Delays in the projected retirement dates of current plants will result in millions of tons of emissions beyond the levels projected.

Second, the projections assume a tripling in the generation of power by nuclear plants between 1985 and 2030. In fact, no new orders for nuclear power plants have been placed for close to ten years and even under the most generous assumptions nuclear capacity will not increase by more than 37%. In the absence of new orders for nuclear plants, capacity may actually begin to decline after 2000.

In an attempt to discount further the need for, or efficacy of, SO₂ emissions reductions in reducing acid deposition, the assessment questions the "linear" connection between SO₂

emissions levels and regional acid deposition. The assessment argues that the possible dearth of hydrogen peroxide molecules, with which SO_2 reacts in the process of acid formation, in regional atmospheres at various times of the year may render SO_2 reductions ineffective in the control of acid deposition. In fact, scientific evidence demonstrates the presence of sufficient oxidants, such as hydrogen peroxide, in the atmosphere to guarantee a linear conversion of SO_2 to acid deposition on a regional and annual average basis. This finding has been confirmed by the National Academy of Sciences which conclusively established in 1983 that reductions in sulfur dioxide emissions would produce proportional reductions in sulfate deposition and acid precipitation.

IV. "Clean Coal" Technology

Finally, the assessment's claim that new coal-burning technology, particularly the process of integrated gasification combined cycle, would solve the problem of sulfur emissions by itself is unsupportable. Contrary to the assessment's assertions, this technology has not been demonstrated as viable at commercial scale. At the same time, available documentation shows that this process has not yet achieved removal of more than one-third of coal-borne sulfur, well below the levels claimed in the assessment.

V. Health Effects

The assessment itself gives the best evidence against a policy of postponing action to control sulfate emissions. According to the assessment, SO_2 hourly concentrations exceeding 100 parts per billion are harmful to many individuals. In fact, such concentrations, though higher than average, are measured routinely over wide areas of the Eastern U.S. In addition, epidemiological studies have found that airborne sulfates may result in a 2 to 5 percent excess morbidity and mortality rate in the U.S. The Office of Technology Assessment has projected that 50,000 premature deaths are caused by airborne sulfates and particulates. Such health considerations alone should dictate immediate action.

VI. Critical Omission: Coastal Water Pollution

The assessment also failed to address the pollution of coastal waters resulting from acid rain. Just two days ago, the Environmental Defense Fund released the results of two years of study of nitrogen inputs into the Chesapeake Bay:

Coastal waters of the eastern United States are receiving large inputs of nutrients, particularly nitrogen, which cause excessive growth of algae, loss

of oxygen and light to the water and long term decline of marine life. The major sources of nitrogen from human activity are thought to be runoff of fertilizer and animal waste from agricultural land, and the outfalls of sewage treatment plants and industrial facilities. The decline of the Chesapeake Bay and other estuaries is attributed in large measure to increasing nitrogen loadings, along with toxic chemicals, pesticides, and wetland destruction.

Here we report that atmospheric nitrate deposition, a component of acid rain, is a major source of nitrogen to the Chesapeake Bay and other Atlantic coastal waters. One-fourth of all nitrogen contributed by human activity to the Chesapeake Bay originates in acid rain and associated dry deposition falling directly on the Bay or onto its watershed. Atmospheric nitrate deposition exceeds sewage outfalls and runoff of animal waste as a nitrogen source to the Bay. Only fertilizer runoff surpasses atmospheric deposition as a source of human-nitrogen. Atmospheric nitrate deposition is a major factor in the decline of coastal waters.

Neither the assessment nor the NAPAP program itself can claim to be complete without extensive research and analysis of the contribution of acid rain to this crucial, if not fatal, ecological problem.

VII. Conclusion

NAPAP is scheduled to end in 1990. Notwithstanding the criticisms put forward in this testimony, we do not believe that this Program or others like it is inherently failure-prone. On the contrary, with or without legislation to limit acid rain precursors, scientific research and monitoring of acid deposition and its ecological impacts will continue to be absolutely imperative. This is particularly true given the equally compelling need to study the interactive relationship between terrestrial ecosystems and the greenhouse effect as well as the relationship between these phenomena and acid deposition and its effects.

These necessary successors to NAPAP whether they be designed to study acid rain or the greenhouse effect will succeed only if such programs are designed in a way that takes their scientific mandates seriously and are insulated from the political exigencies to which NAPAP has been subjected since 1981: legislative battles over acid rain control and an Administration radically opposed to legislation or regulations to control the precursors of acid rain.

Mr. SCHEUER. Thank you very much, Mr. Goffman.

Mr. Goffman, why was it that NAPAP didn't discover the link between acid deposition and nitrate loadings in mid- Atlantic estuaries?

Mr. GOFFMAN. I'm not sure I know the answer to that. But I can speculate that it may have just been a bureaucratic one, that the staff at EPA that's looking at estuaries just was not included in the loop of scientific consideration.

Mr. SCHEUER. Any of you who wish to answer, the Executive Summary contains no discussion of the acid deposition falling on the northeast in the United States or Canada. And they stated that better information will be had when the regional acid deposition model is completed.

Do we truly lack credible information on the source of acid rain in these areas?

Mr. GALLOWAY. You like yes or no answers. This answer is, no, we don't lack that information. We know what the sources are. We know what the direct effects on aquatic ecosystems are. We know the degree of transport.

It was interesting that in the Executive Summary there was no mention of Canada. We know that.

It's also interesting that they didn't mention the fact that there is scientific certainty, as the previous panel pointed out, scientific certainty that there is a large amount of transport from the U.S. to Canada. The net flow goes north. There was not one mention of that in the Executive Summary.

Mr. SCHEUER. The Executive Summary said they didn't include Canada because of the uncertain quality of the data. And Dr. Mahoney said they didn't include the Canadian data because of the non-comparability of that data.

My impression is that the Canadians know what they're doing when it comes to science, and particularly when it comes to the science of investigating and measuring and testing for acid rain, in which they have a tremendous national interest.

This is for any of you. Do you find that a credible statement on the part of the EPA in its Executive Summary that the uncertain quality of the data or, as Dr. Mahoney called it, the non-comparability of the data would have forced its exclusion from the Executive Summary? That enormous body of data delineating and documenting the damage, and which impacts astronomically in excess of ours, on an order of magnitude that we have never experienced in this country.

Mr. LIKENS. I don't understand that statement at all. There are some absolutely outstanding scientists in Canada, aquatic and terrestrially oriented scientists, that have published papers on this issue in some of the most prestigious scientific journals in the world.

And to say that all the Canadian data is suspect, if that's the intent of the comment that we heard this morning, just makes no sense to me whatsoever.

In all of science, as in all of any walk of life, there are high quality results and there are less than high quality results. But that's why we have a peer review system that tries to sort all that out.

But there are some very distinguished Canadian scientists that have worked on this problem and have published on this problem. And it makes no sense to me to ignore those data.

Mr. SCHEUER. The Interim Assessment suggests that research suggests that most watersheds in the northeast are at or near a steady state, implying that few, if any, of the lakes will become more acidic in the near future. Does this statement represent a consensus in the scientific community on this subject?

Mr. GALLOWAY. Go ahead.

Mr. LIKENS. Not at all. I commented on this in my prepared testimony. The idea of a steady state, in terms of an ecological system, is a very complex issue.

What they are purporting to talk about here is a steady state relative to sulfur deposition and sulfur retention in water bodies. But the issue here is much more complicated than that.

And, again, the more fundamental problem is that it's looking for a single factor kind of solution to a very complex problem. And nature, unfortunately, doesn't work that way.

But there are many examples in which it appears that the sulfur system is not in a steady state at all in the northeastern United States. And this is kind of a broad brush look at sulfur inputs and retention and losses from lakes that I don't think there's any general agreement on at all.

I think it's a major problem in the assessment that needs to be looked at in the next two years and evaluated carefully.

Mr. SCHEUER. I want to thank you all for your splendid testimony.

It's sometimes been said in reference to your answer, Dr. Likens, that for every very complicated question there's always a very simplistic answer, and it's invariably wrong. I think we have a dramatic case of that at the present time.

You've all been very patient. You've been very forthcoming, and have given us thoughtful testimony. We thank you very much.

We may have some questions for you, and we're going to hold open the record for 10 or 12 days to submit further questions by mail.

Thank you very much for coming.

The meeting is adjourned.

[Whereupon, the Subcommittee recessed at 1:10 p.m. to reconvene at the call of the Chair.]

APPENDIX I

Canadian Embassy



Ambassade du Canada

*NRAPE*1746 Massachusetts Ave. N.W.
Washington, D.C. 20036

January 7, 1988

The Honorable James Scheuer
2466 Rayburn House Office Building
Washington, D.C. 20515

Dear Congress Scheuer,

On September 17, 1987, the National Acid Precipitation Assessment Program (NAPAP) released its interim assessment report. On September 18, the Honourable Tom McMillan, Minister of the Environment, expressed strong concerns about the Report's Executive Summary and indicated in a letter to Mr. Lee Thomas, Administrator, Environmental Protection Agency, that Canada would provide a thorough scientific critique of the Report.

Enclosed for your information is a copy of the critique which recently was provided to Mr. Thomas. For ease of reference enclosed as well is a copy of the letter sent to Mr. Thomas from Mr. McMillan at the time the critique was forwarded to Mr. Thomas.

My officials would be pleased to respond to any questions from your staff on this important issue.

Yours sincerely,

*Allan Gotlieb*Allan Gotlieb
Ambassador

January 6, 1988

Mr. Lee Thomas,
Administrator,
United States Environmental
Protection Agency,
1200 West Tower,
Washington, D.C. 20460
U.S.A.

Dear Lee,

I am writing further to my letter of 17 September regarding Canadian concerns about the NAPAP Interim Assessment - The Causes and Effects of Acidic Deposition, and to our subsequent meeting on 29 September.

Canadian scientific experts have now completed their analysis of the NAPAP report. I have enclosed a copy, for your reference. Our initial judgment in September was that the report's Executive Summary was flawed, incomplete and misleading. On the basis of intensive review by Canadian scientists, our concerns now go beyond questions of science to the overall thrust and intent of the document.

The Executive Summary portrays the problem of acid rain as neither serious nor in need of any intervention. It minimizes what is known about the matter, over-complicates what is uncertain, and describes a market-driven future in unreasonably optimistic terms. The clear deficiencies in the Executive Summary should invalidate it as an element in developing the Administration's response to the already serious and worsening transboundary problem of acid rain.

The description of past sulphur dioxide emissions, for example, notes that, overall, emissions have been within plus or minus 35 percent of the 1985 value since about 1910. A more appropriate presentation would have noted that emissions have, in fact, increased significantly during the 20th century. The Executive

Summary could have stated that U.S. SO₂ emissions have increased by more than 200 percent since 1900 and that the impact of this development may have been worsened by the growing number of tall stacks.

The forecast of future emissions is equally misleading. The Executive Summary suggests that utility emissions will decrease by 55 to 80 percent. This estimate assumes the full implementation of advanced technologies on all new and replacement power plants coming on line after 1995. In the past, U.S. Environmental Protection Agency forecasts of emissions have been based primarily on regulatory requirements. The Summary presupposes an extraordinary policy shift to reliance almost exclusively on anticipated market forces. The Summary also fails to note that the emission forecast is based on a 300-percent increase in nuclear power generation over 1985 levels. From what Canadian officials understand about the nuclear power industry in the United States, that assumption can only be described as wishful thinking.

The criteria chosen to define the extent to which lakes are being damaged by acid rain unreasonably minimize the seriousness and geographic extent of the problem. A threshold of pH 5 was used in considering a lake to be damaged, even though the U.S. Environmental Protection Agency has irrefutable evidence that serious damage begins to occur in lakes at a pH level of 6. A simple look at the data shows how the selection of the pH 5 threshold value drastically reduced the number of lakes identified as affected and thus downplayed the seriousness of the problem.

Percentage of Lakes

Area	<u>below pH 5</u>	<u>below pH 6</u>
Adirondacks	10	20
Catskills and Poconos	0.8	11
Maine	0.5	3
Southern New England	5	13

Even these data present an over-optimistic picture. For the Eastern United States, only lakes greater than four hectares in area (about 10 acres) were counted. The Executive Summary itself, however, states that more small lakes and ponds in the eastern United States have low pH values than do larger lakes.

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The Summary goes on to argue that the lakes and streams are "at or near steady state with respect to sulfur deposition and that further significant surface water acidification is unlikely to occur rapidly at current deposition levels." Data from numerous sources, including the U.S. Electric Power Research Institute, the U.S. Environmental Protection Agency and the Ontario Ministry of Environment, all contradict the so-called steady-state theory. Except for a few specific cases, that theory simply cannot be supported.

In its mandate to the NAPAP, the U.S. Congress expressed concern over the potential impact of the long-range transport of air pollutants on both national and international policy. Canadian scientists gave the NAPAP Director of Research the information needed to review the effects of acidic deposition in Canada. Furthermore, most of the information had been agreed on by Canadian and U.S. scientists and used in the recent bilateral report entitled Status of Canadian/U.S. Research in Acidic Deposition. There is no valid reason why that material, which shows the extensive and serious nature of the problem in Canada, was not used.

From our perspective as the United States' closest neighbour, this last aspect is the most disturbing. In April 1986, following a thorough review of the problem by their Special Envoys, Prime Minister Mulroney and President Reagan agreed that:

acid rain is a serious environmental problem in both the United States and Canada; and, acid rain is a serious transboundary problem.

The NAPAP report has ignored the conclusions of the Special Envoys, which were endorsed by our heads of government.

The facts that convinced President Reagan and Prime Minister Mulroney include the following:

- more than half of the acid deposition in eastern Canada originates in the United States;
- some 14,000 lakes in eastern Canada

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- have pH levels of less than 5;
- some 150,000 lakes in eastern Canada have pH levels of less than 6;
- thousands of eastern Canadian lakes have lost from 60 to 80 percent of their ability to neutralize acidic fall-out due to deposition of sulphates; and
- thousands of eastern Canadian lakes continue to be damaged biologically and chemically at current emission/deposition rates.

Two years ago, the Special Envoys stated that the major task before our two countries was the conclusion of a bilateral accord to address the serious transboundary problem of acid rain. The need to do so remains as urgent and important as ever.

Yours sincerely,

Tom McMillan, P.C., M.P.
Hillsborough

Minister of the Environment

A Critique of the U.S. National Acid Precipitation
Assessment Program's Interim Assessment Report

PREFACE

This document is made up of two parts, an overview and the detailed report. The overview presents the main criticisms of the NAPAP document.

The detailed report follows the design of the Interim Assessment, consisting of eleven parts, an Executive Summary and ten chapters.

This critique presents comments in the same order that the pertinent sections appear in the Assessment Report. As a consequence, important criticisms and lesser problems, for example typographical errors, are all mixed together. In order to assist the reader in extracting the major criticisms of the report, these are identified in bold type.

In some instances, comments on the Executive Summary are noted again later in one of the ten following sections where the subject is discussed in detail.

This document has been prepared by the Canadian Federal/Provincial Research and Monitoring Coordinating Committee (RMCC) for the National Acid Rain Research program. The names of reviewers who contributed to this critique are listed in Appendix 1. Additional copies may be obtained from Dr. H.C. Martin, Secretary, RMCC, Atmospheric Environment Service, Environment Canada, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4.

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A CRITIQUE OF THE U.S. NATIONAL ACID PRECIPITATION

ASSESSMENT PROGRAM'S INTERIM ASSESSMENT REPORT

DECEMBER 1987

Prepared by

FEDERAL/PROVINCIAL RESEARCH AND MONITORING COORDINATING COMMITTEE

(RMCC)

A Critique of the U.S. National Acid Precipitation
Assessment Program's Interim Assessment Report

OVERVIEW

This critique presents Canada's response to misleading, flawed, and incomplete conclusions of the NAPAP Interim Assessment Report. Additional details on misrepresentations, omissions and corrections relating to the Executive Summary and the ten technical chapters follow this overview.

The Executive Summary of the U.S. National Acid Precipitation Assessment Program Interim Assessment report entitled "The Causes and Effects of Acidic Deposition" suggests five basic conclusions:

- I The effects of acid rain are neither widespread nor serious
- II There will be no abrupt changes in the effects of acid rain for the next several decades
- III Emission levels of sulphur dioxide have been nearly constant since the 1920's, are currently stable, and will decrease substantially over the next three to four decades through the application of new technologies due to market forces.
- IV The effects of acid rain are less than were anticipated ten years ago
- V Sufficient uncertainties remain to preclude determining whether abatement action is needed or the nature of that action

These "conclusions" misrepresent the information contained in the main body of the NAPAP report and have failed to take account of pertinent and relevant information omitted from the report.

I Fact: The Effects of Acid Rain are Already Widespread and Serious.

The NAPAP Executive Summary used a pH of 5.0 as the definition of a lake which is being affected by acid deposition. Information contained in the main body of the report and from other sources indicates that this is an unduly restrictive definition, which minimizes both the seriousness and geographic extent of damage.

Canadian and American scientists have shown that biological effects due to acidification occur for some aquatic species near pH 6.0 with many species disappearing in the range pH 6.0 to 5.0. In lakes where pH values average below 5.0, most fish species, virtually all molluscs and many benthic invertebrates are eliminated. Therefore, a value of 6.0 is a more appropriate threshold below which adverse effects occur.

Canadian scientists have estimated the number of lakes in eastern Canada affected by acid deposition. Approximately 700,000 lakes in eastern Canada receive acid deposition at greater than 20 kilograms per hectare

per year of wet sulphate. Of this total aquatic resource, approximately 14,000 lakes have acidity levels of 5.0 or less. There are approximately 150,000 lakes with a pH less than 6.0, the acidity level at which detrimental biological effects begin to occur.

An additional indicator of the extent and severity of damage to surface waters is their alkalinity deficit. Analysis of surface water chemistry based on data from about 8,000 lakes shows extensive deficit of alkalinity in lakes in eastern Canada. The greatest alkalinity deficit occurs in areas of greatest sulphate deposition caused by the long range transport of air pollutants. The analyses demonstrate that large areas of south-central Ontario, southern Quebec, New Brunswick, Nova Scotia and Newfoundland already suffer serious and widespread effects due to acid rain. Similar patterns have been identified for surface waters in the United States. The relevant maps have been provided to the NAPAP.

Damages to terrestrial systems have been downplayed in the Executive Summary by inappropriately separating acidity impacts from the rest of the long range transport of air pollution effects. Some of these stresses are treated singly in the Summary. A large portion of the multiple air pollution stress impacting on terrestrial systems results directly from emissions of SO_x and NO_x . These emissions lead to acid mists and fogs, ozone production, the depletion of base cations in soils, and the release of toxic and phosphorous-immobilizing aluminum. This critical linkage, and the associated concern with widespread terrestrial effects, is not reflected in the report.

II Fact: The Effects of Acid Rain Are Worsening

Canadian and U.S. scientific information demonstrates that sensitive lakes in eastern North America are not in a steady-state with respect to current levels of emissions/deposition and that chemical and biological deterioration is continuing.

A study, conducted at Plastic Lake (a representative sensitive lake) and Harp Lake (a representative insensitive lake) located in south-central Ontario, provides direct observations of the continuing deterioration of lake water chemistry and damage to aquatic biota in acid sensitive lakes despite a reduction of acid deposition.

Over a recent seven-year period, alkalinity at Plastic Lake, decreased by a factor of three and the acidity level increased by 67 per cent while wet sulphate deposition decreased from about 40 kilograms per hectare per year to about 30 kilograms. At Harp Lake, an insensitive lake in the same area, no changes in alkalinity or acidity levels were observed.

Based on extensive lake survey data, the Plastic Lake information is typical of the many thousands of sensitive lakes in eastern Canada.

Paleoecological studies of Adirondack lakes corroborate these observations as does the text of the main body of the NAPAP Interim Assessment. These systems have not reached equilibrium.

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III Fact: The U.S. SO₂ Emission Pattern Has Changed Profoundly Over the Past Decades and Emission Levels Will Not Decrease in the Foreseeable Future

The contribution of the U.S. SO₂ emissions to the long range transport problem has been increasing over the last three decades due to the increased use of tall stacks. As a result, the sulphate deposition in sensitive areas of Canada has certainly not been constant since the 1920's.

The NAPAP report concluded that U.S. SO₂ levels have been essentially unchanged since the 1920's, will remain stable for the next 10 to 15 years and then decrease significantly over the following 10 to 20 years as new advanced control and combustion technologies are implemented, due to market forces.

U.S. emissions are much more likely to increase in the next 15 to 20 years as U.S. utilities both increase the use of existing power plants, which are essentially uncontrolled, and extend their life expectancy through refurbishing. Canadian experts, and many U.S. commentators have concluded that, in the absence of economic incentives or regulatory requirements, there will be only limited application of advanced pollution control and combustion technologies on existing power plants over the next 30 to 40 years.

IV Fact: The Acid Rain Problem is Worse than Was Anticipated Ten Years Ago

The current and potential damage to the environment from acid rain is much more wide-ranging and serious than anticipated 10 years ago. Damage to sensitive lakes is occurring more rapidly than originally anticipated and at much lower levels of acidity. Forest injury in some parts of the world has been devastating. Effects on groundwater, soils, materials and human health are emerging as areas of concern.

V Fact: What is Known About the Nature, Causes and Effects of Acid Rain Is Sufficient to Design Effective Abatement Programs

The important facts in deciding what to do about controlling acid rain are very clear.

- Sulphur is causing damage in aquatic and terrestrial systems, materials and perhaps human health.
- Canadian studies have shown that reducing sulphur dioxide emissions will result in a proportional reduction in sulphur loading over large areas. For example, total sulphur dioxide emissions from sources within 500 km of southern Nova Scotia decreased by about 25 per cent over the period 1971 to 1983. Sulphate deposition, as estimated from runoff measurements, decreased from about 39 kilograms per hectare per year to about 21 kilograms over the same period. Current computer models of the atmosphere linking emissions with deposition of sulphate can duplicate the above results sufficiently to guide control scenarios.

COMMENTS ON THE EXECUTIVE SUMMARY

General

The Executive Summary is described as "a presentation of the state of the science with sufficient theoretical background to enable the general reader to review the results." However, rather than trying to reflect the best scientific judgement of the present understanding of acid rain, the Executive Summary appears to be designed to support the preconceived policy position that further control action is not warranted. This is done through the selective use of the total North America information base and through inaccurate reflection of the data in the report in the Conclusions of the Executive Summary. Major omissions include:

Atmospheric

- There is no discussion of trajectories which show where the air is going, including the relative importance of meteorology versus chemistry in source-receptor predictions.
- There is a great deal of discussion on non-linear relationships between emissions and wet deposition. The fact that dry deposition, which can account for 20-50% (or more) of the total, is a linear process, is not mentioned in the assessment. The work of the U.S. National Research Council (NRC) concerning the question of linearity is not mentioned. The NRC found that, on the basis of data available (to 1983), there was no evidence for a strong non-linearity between long-term average emissions and deposition. (See page 4-65, section 4.6.1)

Forestry

- There is no mention of the unexplained dieback of low elevation hardwood forests in the northeastern U.S.A. and southeastern Canada in recent years, particularly the extensive dieback of sugar maple in Quebec. This dieback is located in the region of heaviest deposition and may be a phenomenon in which acid deposition plays a major role.

Aquatics

- The Canadian modelling and survey results which demonstrate a very severe acidification problem for surface waters are omitted. These Canadian data were provided to the NAPAP in February, 1987, and the interpretation agreed to in the Bilateral Advisory and Consultative Group (BACG) report of April 1987. An updated version was provided on request to the Executive Director of Research for NAPAP in July, 1987.

In addition to these serious omissions, there are many general and specific shortcomings.

The obsession with the development of an Eulerian model is inexplicable in scientific terms. The whole existing hierarchy of accepted methods of increasing sophistication which are available to estimate source-receptor

relationships are not discussed. The methods range from the simplest qualitative pattern association through regional budget studies, trajectory sector analyses, tracers of opportunity, analysis of impact of known emission changes, and statistical and Lagrangian transport models.

In the discussion of forestry effects, it would be appropriate to indicate that, if a nil hypothesis cannot be rejected, it may be either because of inadequate sampling and techniques or because the response does not occur. The text gives the impression that since nothing has been seen yet, nothing is likely to occur, other than ozone effects. The probability that effects will or will not be seen, is purely speculative.

The "general" conclusion (page 1.31), "acid deposition has contributed to the acidity of some northeastern and mid-western acidic lakes" does not agree with either the text or the preceding conclusions. The statement, to be accurate, should read "acidic deposition has led to acidic conditions in numerous lakes and streams of the northeast and upper midwest of the United States."

There is no mention of the implication of pH depression in spring runoff, a consequence of a build-up of chemicals in the snowpack. In northern and northeastern portions of the U.S., this phenomenon constitutes a serious risk to aquatic biology.

The discussion of amelioration of acid rain effects refers to liming of watersheds and coating of materials. "Liming of watersheds to restore fishing conditions" is not practical for eastern North America for economic reasons alone, given the size of the resource at risk. "Coating of materials" is not yet a practical method for many cases. Coating statues and other monuments is unacceptable for aesthetic reasons. (See page 1-5, section 1.1.5.2.)

The report states that health effects uncertainties will not be resolved by 1990. Ironically, the bulk of the health work conducted in the U.S.A. has not been reviewed. If the 1990 report is not more comprehensive, then, for this reason alone, it is expected that the NAFAP will not be able to resolve uncertainties. (See page 1-8, section 1.3.1.1.)

The report states that source-receptor relationships will not be resolved by 1990. The relationship for major sources is now available but was not discussed in the report. (See page 1-8, section 1.3.1.1.)

Section 1.3.1.6. on "Different Acid Rain Precursors Lead to Different Effects" discusses a wide range of pollutants and impacts. The uncertainties raised give an unbalanced picture. A great deal is known, particularly with regard to the damage caused by sulphur compounds in lakes, for example.

There are many studies which clearly demonstrate that sensitive lakes in the Northeastern part of the continent are not in steady state with respect to current levels of emission/deposition and that chemical and biological deterioration is continuing (most recently Dillon *et al*, 1987, Nature). These observations contradict the conclusion of the report.

The report refers to "acidic lakes and streams (pH less than 5.0) ..." in various places throughout the documents. This definition totally ignores the consequences of acidification below pH 6 for biological communities. The use of pH 5 as a reference point for injury to aquatic systems is a major misjudgement of the science available.

Ambient acid precipitation will not likely directly impact agricultural crops. However, there are consequences of acid being deposited on soils, especially those of low acid buffering capacity. The quality of the soils must change unless they are limed.

The report notes that aside from peaks and troughs, "sulphur dioxide emissions in 1985 (21 million metric tonnes) were about the same as in the late 1920's". Tall stacks have significantly increased the distance over which pollutants travel. They have also centralized the emissions at specific points. The report notes "as a result, it is assumed that for the same quantity of sulphur dioxide emitted, the sulphur dioxide concentrations, rain acidity, and dry deposition decreased in most urban areas and increased in some rural areas over the last three decades." Nowhere in the document are the consequences of the tall stacks and the change in emission patterns discussed in terms of cumulative effects. (See page 1-10, section 1.3.2.1. and page 1-12, section 1.3.2.6.)

The Executive Summary presents the conclusions drawn on Health and Visibility with some selectivity, reflecting the best news in Chapter 10. In general there appears to be an attempt to discount the role of acidic aerosols on human health. The absence of data does not support a negative association any more than it would support a positive one.

Specifics

No reference is made to the historical reductions in SO_2 emissions that have occurred in Canada although these are discussed in the text.

No reference is made to the Canadian acid rain control program with specific SO_2 reductions.

The choice of words "in some rural areas" downplays the real impact of the tall stacks. It would be more appropriate to refer to "increased in large regions downwind over the last three decades". (See page 1-12, section 1.3.2.6.)

The estimates of reduced SO_2 and NO_x emissions due to new technology are high. Simultaneous large SO_2 and NO_x reductions are limited to very few technologies. In addition, NO_x reductions above 35% can be difficult in some boiler types.

In-duct sorbent injection with efficiencies of 50-70% reductions are normally associated with SO_2 , not NO_x . (See page 1-15, section 1.3.3.5)

Selective catalytic reduction (SCR) is well beyond the developmental stage with some 8000 MW of generating capacity installed in Germany. (See page 1-16, section 1.3.3.)

The base case (no new advanced technology) shows emissions rising between 1985 and the year 2000 by about 15%. The report fails to comment on the magnitude and implications of this increase. Put into the Canadian context, this U.S. rise by about 15% between now and the year 2000 has serious transboundary flow implications and, in fact, will be more than half of the total SO_2 emissions in Canada in 1994 (target emissions under regulations equal 2.3 million metric tonnes). In the U.S. context, the text says that emissions will remain "roughly constant" during the period 1985-2005. (See page 1-17, section 1.3.4, sub-section 1.3.4.1.)

The report states "Organic acids contribute to the acidity of precipitation" without further explaining that in eastern North America the contribution is insignificant. (See page 1-20, section 1.3.5.4.)

The discussion of atmospheric models states that advanced regional models are being developed, tested, and evaluated. No reference is made to current models available for the development of source-receptor relationships. Not only is the omission of current model evaluation a serious shortcoming in the Executive Summary, but the suggestion that the complex models will be "available in 1989-90 for application in simulating source-receptor relationships", is totally unrealistic. The preparation of a data set for evaluation will not be complete in 1989, let alone the application of the model to policy questions. (See page 1-22, section 1.3.5.7.)

One could conclude from the examination of eight forest declines that, since two cases were proven to be caused by air pollution and six cases could not determine the importance of air pollution, then, there is good reason for action on pollution controls. (See page 1-27, section 1.3.8.1.) The conclusion regarding the impacts of ozone on low elevation forests is extremely important, noting that ozone reduces tree photosynthesis, growth and resistance to other stresses. (See page 1-29, section 1.3.8.4.)

The Executive Summary concludes that "human welfare is potentially impacted by reductions in visibility through changes in transportation safety, property values and aesthetics." This statement is in marked contrast to the conclusion contained in the WMO report of some years ago "given this widespread occurrence of visibility reduction due to sulphate aerosols, international pollution control strategies aimed at sulphate abatement must be considered by governments of industrialized nations if further deterioration of visibilities are to be avoided, or if improvements of existing visibilities are to be attempted" (World Meteorological Organization: Environmental Pollution Monitoring Program Report, Report #14, Effects of Sulphur Compounds and Other Air Pollutants on visibility, April, 1983.) (See page 1-35, section 1.3.11.6)

Technical and Editorial Comments

It is stated that "most of the mechanisms by which pollutants become attached to droplets are significantly well understood ..." This is an optimistic and somewhat misleading interpretation of the material contained in the text.

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Reference is made to hydroperoxyl and peroxy. Should these not read hydroperoxy and peroxy?

The Executive Summary states that "measured concentrations of the hydroxyl radical are less than those predicted by models", accounting for the difference through model inadequacies. This is not entirely correct since some measurements and model calculations are consistent. In addition, the inconsistency may lie in the measurement technique, not in the model. (See page 1-19, section 1.3.5.1.).

The availability of ozone in the troposphere via stratospheric intrusion is not mentioned. (See page 1-19, section 1.3.5.1.).

In the discussion of ozone production, does the ozone production rely on the concentrations of volatile organic compounds or on hydrocarbons? (See page 1-19, section 1.3.5.1.).

Hydrogen peroxide (H_2O_2) is also formed from the combination of hydroxyl radicals, a process which is not mentioned. (See page 1-19, section 1.3.5.1.).

In the discussion on the formation of sulphuric acid, the Executive Summary neglected to mention that the sulphur dioxide hydroxyl radical reaction is the main oxidation reaction with other reactions including HO_2 , CH_3O_2 ... etc. (See page 1-19, section 1.3.5.2.)

In the discussion the "Formation of Nitric Acid" the involvement of PAN is not mentioned. (See page 1-20, section 1.3.5.3.)

"There is no scientific consensus on the relative importance of gas phase and aqueous phase production of sulphuric acid". This contention is debatable since there is general consensus in the literature. (See page 1-20, section 1.3.5.4.)

There is no reference to heterogeneous reactions leading to SO_2 oxidation. These should be mentioned since they are important. (See page 1-20, section 1.3.5.4.)

"There is no evidence that significant amounts of nitric acid are formed from aqueous-phase oxidation of nitrogen compounds". Scavenging ratio calculations have suggested in-cloud oxidation to produce nitric acid, hence, there is evidence. (See page 1-20, section 1.3.5.4.)

The description of scavenging of air pollutants is incomplete since it does not note the difference between snow and rain scavenging nor the difference between the scavenging of gases and particles. (See page 1-20, section 1.3.5.4.)

The "small particles" size is not defined. The specific size is important in terms of effects. Is the cut-off at $2 \mu m$? (See page 1-20, section 1.3.5.5.)

The Executive Summary does not note the great diurnal variation in dry deposition. Also, the dry deposition for particles is generally less well known than that of gases. (See page 1-20, section 1.3.5.5.)

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"On average the ratio of the contribution of fine sulphate particles to sulphur dioxide dry deposition as sulphur is about 1:4." This ratio is too general and does not take account of the dependence on distance from source and on season. (See page 1-21, section 1.3.5.5.)

The paragraph on the measurement of dry deposition should indicate that concentrations are measured and surrogate surface characteristics are used to calculate dry deposition. (See page 1-21, section 1.3.5.5.)

The statement that "nitrogen dioxide is readily transformed to nitric acid ..." should be expanded to define "readily". Also, a one-day residence time may not be a short distance (a mean wind of 25 miles per hour moves air 600 miles in a day). (See page 1-21, section 1.3.5.5.)

In the discussion of wet and dry deposition of sulphur dioxide and ozone no reference is made to ammonia which is important in the deposition process. (See page 1-21, section 1.3.5.5.)

The section on transport and dispersion suggests that only general information is available. Experiments such as WATOX (Western Atlantic Ocean Experiment) should have been referenced. (See page 1-21, section 1.3.5.6.)

The discussion of summer-winter differences should note the change in scavenging rates with season, as well as the comments on reaction rates and meteorology. (See page 1-21, section 1.3.5.6.)

The reference to the conduct of future modelling work in a "scientifically credible manner" discredits the work of current modellers in the U.S.A. and elsewhere who have attained major success in the development of simple models with impressive performance when tested against field data. (See page 1-22, section 1.3.5.7.)

The report states that EPA monitoring data, primarily from urban sites, shows 36% decrease in SO_2 concentrations from 1975-1984, "consistent with the downward trend in national emissions of SO_2 during this period". The shift from urban to rural power plant sites, changes in stack height, etc., should also be noted as contributors to the concentration decrease. (See page 1-22, section 1.3.6.1 and page 5-15, section 5.2.2.2.)

One must question the representativeness of the ozone concentration figure since at most stations there are only two observations for the four years. It would be risky to consider the figure to be representative of what might happen during any given year. (See page 1-23, Figure 1-10.)

The discussion of deposition states that, "at more than one half of the 44 sites evaluated, sulfate, calcium, magnesium and hydrogen ion deposition decreased". No indication is given of the error or uncertainty in the data due to the number of samples collected. The statement is misleading. One could equally say "at nearly half of the sites the sulphate and hydrogen ion deposition increased". (See page 1-24, section 1.3.6.2.)

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The basis for the statement that the natural background pH "may have been as low as 5", is not very strong. In fact, it "may not have been" as low as ... (See page 1-25, section 1.3.6.2.)

The discussion of sulphate and nitrate background values does not note the difficulty of determining background concentrations. In the high arctic where there are no sources "the background" can be associated with anthropogenic emissions in Asia and North America. The uncertainty is quoted as being a factor of 3. Does this suggest that annual depositions of sulphate in northeastern United States might have been 18 kg/ha in the past, before industrialization occurred in North America? (See page 1-25, section 1.3.6.2.)

The region "probably" receiving 60 kg/sulphate/ha "may" include, of course, a large portion of southwestern Ontario. (See page 1-25, section 1.3.6.4.)

The discussion on agricultural crops does not provide any indication of the limitations imposed by the experimental conditions involved in the studies. (See page 1-25, section 1.3.7.)

In addition to the potential impacts of hydrogen peroxide on trees above cloud base, the interaction of pollutants, including acidity and excess nitrogen and ozone, along with natural factors must be considered. (See page 1-29, section 1.3.8.5.)

The Executive Summary states "a significant increase in visibility has been observed since 1970 over the industrial states" etc. (Page 1-35 which is identical to the conclusions section on page 10-71, section 10.5.3.) Within the text the statement is somewhat different, referring to high winter haziness continuing in the Ohio basin with summertime haziness increasing until the 1970's, followed by a significant decline since 1977. Hence, the Executive Summary conclusion applies only in the summer.

The Executive Summary (and conclusions of the visibility section) states that the summer visual range in rural areas is approximately 20-30 km in the east and 75-200 km in the west. The information presented in the text disagrees with this number, suggesting that eastern U.S. haziness is above $300 \times 10^{-6} \text{ m}^{-1}$, which correspond to less than 13 km visual range for the summer. This is a factor of 2-3 discrepancy. (See page 1-35, section 1.3.11.6.)

CHAPTER 1

Emissions of Acidic Deposition Precursors

General

The report provides an excellent description of the major sources of emissions of SO_2 , NO_x , and volatile organic compounds in North America, including the work required to improve accuracy of estimates.

Historic emission data are factual for both Canada and the U.S.

Specifics

The Canadian and U.S. emissions are described for 1980 on a per capita and per U.S. dollar of GNP basis. A more useful characterization might be SO_2 emissions per unit amount of coal consumed (for utilities the ratio in the U.S. is 0.028 and in Canada 0.022). (See page 1-12, section 1.3.1.)

Chapter 1 states that emissions of SO_2 from utilities will decrease as SIP-controlled plants are retired and more stringently controlled units are put in place. This scenario is not certain and will depend in part on economics. (See page 1-28, section 1.4.1.2.)

No reference is made to a 54% decline in emissions from the major contributor in eastern Canada, non-ferrous smelters, between 1955 and 1984. Instead the 45% reduction between 1970 and 1980 is presented. (See page 1-31, section 1.4.1.3.)

CHAPTER 2

Emission Control Technologies

General

The statements relating to control of automobile emissions are true and accurate. The overview on coal cleaning technology is good. The discussion pertaining to power utilities should prove to be a useful reference document on emission control technologies.

Specifics

The synopsis seems to contain an inconsistency. On page 2-I, the text states "low nitrogen oxides burners are commercially available to reduce nitrogen oxides emissions from new and existing coal-fired power plants by about 50%". On page 2-II, it states "In almost all cases, technology exists to remove 90+% of sulphur dioxide (usually at high costs), but only 25-35% of nitrogen oxides". Canadian experience with Ontario Hydro supports the second statement with anticipated reductions no more than 35%. (See page 2-i and ii, Synopsis)

Depending on the proportions of pyritic and organic sulphur in coal, the total sulphur removal can be as high as 50% in cleaning. (See page 2-6, section 2.2.2.2.)

Coal cleaning should be discussed in terms of sulphur removal and economic benefit due to ash reduction, transport costs, etc. (See page 2-6, section 2.2.2.2.)

Beneficiation of lower rank western coals (reduced moisture and gas) should have been considered in view of the increased BTU content and reduced SO₂ emissions. (See page 2-6, section 2.2.2.2.)

Chemical cleaning processes are very costly and, hence, commercialization by 1995-2000 is not likely. (See page 2-8, section 2.2.2.2.)

50% removal efficiency for low NO_x burners may be possible only for a limited class of boilers and conditions. (See page 2-11, table 2.5.)

The discussion of integrated coal gasification combined cycle (IGCC) reports emissions of approximately one-tenth of the sulphur dioxide and nitrogen oxides generated. This may be possible only in certain boilers. (See page 2-21, section 2.2.3.2.)

The discussion of the Ontario Hydro sorbent injection experiment should note that low-sulphur bituminous coal and low/medium sulphur bituminous coal blends are used as well. In addition, the Ontario Hydro and the Saskatchewan Power test programs both include convective gas injection and the Ontario Hydro program includes low temperature injection. (See page 2-44, section 2.2.5.1.)

The document states "low nitrogen oxides burners provide an increased level of nitrogen oxides control, with reported removal efficiencies of 45-60%". Canadian experts disagree with the high efficiencies quoted. (See page 2-51, section 2.2.5.2.)

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The text states "in Europe, approximately 2200 MW of SCR was operating as of February 1987." A recent report "Control Activities in Europe" co-authored by Batelle Memorial Institute shows some 8000 MW of flue gas de-nitrification capacity in Germany, most of which is SCR. (See page 2-52, section 2.2.5.2.)

The cost of flash smelting seems to be too high. According to the presented values, the Sudbury compliance with regulations will cost \$800 million. (See table 2-19.)

CHAPTER 4

Atmospheric Processes

General

This chapter is a thorough review of our understanding of atmospheric processes. There are, however, some important exceptions which are noted below.

One of the major oversights in this section is a complete omission of Canadian work on cloud chemistry, in particular, two projects which were jointly conducted by a U.S.-Canadian team. There is little mention of Canadian papers on scavenging, vertical profiles and dynamic interactions.

The discussion of Transport and Dispersion (4.5) is weak because of some important omissions. There is a lot of useful work on trajectories which shows where air goes. It is not included. The discussion of the relative importance of meteorology versus chemistry should also be included (sensitivity of source-receptor predictions). The discussion of differences between summer and winter meteorology and day and night suggest that these are complicating factors. They are really quite well known aspects to meteorologists.

The assessment downplays the good performance of existing models with long-term data evaluations. Their good agreement with independent analyses of air quality data is not mentioned at all. The June 1987 APCA Annual Meeting in New York included a discussion of the contribution of mid-western emissions to northeastern atmospheric acidity. The three independent analyses all showed contributions in good agreement with the estimates of linear LRTAP models. The report suggests that the regional atmospheric deposition model (RADW) will be available in 1989/90. This is highly unlikely. The model has to be evaluated. The field data collection will start June 1988 and will be completed June 1990. After that time a minimum of six months will be required before final evaluation data are available. Hence, the evaluation may optimistically be completed on or about June 1991.

There is no mention of the association between emission areas and areas receiving high levels of deposition. The extensive trajectory analysis work carried out by various workers, and the evidence for source-receptor relationships provided by this work is omitted.

Specifics

The section on aqueous phase transformation does not refer to Canadian papers. In particular, reference to important joint U.S.-Canadian studies is not made. (See page 4-30, section 4.3.3.)

The comment concerning late spring high concentrations of ozone at clean rural and remote sites due to intrusion of stratospheric ozone may be overstated. (See page 4-34, section 4.3.5.)

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Section 4.4 is a valid presentation of our current understanding of dry deposition. (See page 4-37, section 4.7.4.)

The discussion of the CAPTEX does not do justice to the good performance of the Lagrangian models. Nonetheless, the performance of models as noted is not nearly as dismal as suggested elsewhere when Eulerian models are discussed. (See page 4-63, section 4.5.3.)

The report notes "this implies that sulphur has an important long-range transport component". This is true and is consistent with the transport into Canada. (See page 4-64, section 4.5.3.)

The discussion on linearity does not make reference to the important document by the National Academy of Sciences on this topic. One of the conclusions was that on an annual basis, the non-linearity problem is not serious when one discusses regions. (See page 4-65, section 4.6.1.)

It is noted that Lagrangian models are good for giving source-receptor relationships but have poor chemistry. On the other hand, Eulerian models have good chemistry but cannot directly give source-receptor relationships. The text then completely dismisses Lagrangian models. This is disturbing. The further discussion on source-receptor relationships quotes the review paper by Hidy (1984, J. APCA) and the response by Durham and Foley (1984, J. APCA), but ignores the relevant comments by Summers (1984, J. APCA). (See page 4-66, section 4.6.3.)

Millions of dollars are now being spent on the Regional Acid Deposition Model (RADN) development. The Executive Summary does not refer to models already available. (See page 1-21, section 1.3.5.7.) "It became evident during the technical meetings held in 1979 under the United States-Canada Memorandum of Intent on Transboundary Air Pollution that chemical and wet deposition processes (and hence, response SRRs) leading to acidic deposition are likely to be nonlinear for sulfur and nitrogen compounds." (This should be 1980.) In addition "existing regional transport and deposition statistical and Lagrangian models over-simplify the mathematical representation of the processes especially those of oxidant formation, oxidant reactions with sulphur dioxide and nitrogen oxides and wet scavenging for reactive gases. The credibility of the output of those Lagrangian models for application and policy analysis and assessment was questioned". Are we to believe that nothing has happened since 1979 in the development of the Lagrangian model approach? Didn't the National Academy of Sciences agree that a linear approach for large regions and annual evaluations was acceptable? Haven't the Canadian and U.S. modellers recently tested a wide range of Lagrangian models and found some of them predicted the measured field deposition values on an annual basis to an accuracy equal to the capability of the networks to provide measurement data? Yet we read in the assessment document "thus NAPAP is not pursuing statistical and Lagrangian models for producing SRR's [Source-receptor relationship]". What is the reason? (See page 4-67, section 4.6.4.)

The complex Eulerian models do not calculate source-receptor relationships and must be modified "to devise ways to obtain the SRR's". In addition, the complex models (RADN and ADOM - Atmospheric Deposition and Oxidants Model) "require excessively large computer resources to

generate SRR's". To overcome this difficulty, the complex models are being simplified and examine sulphur only. The NAPAP program intends to produce seasonal and annual averages of concentrations and deposition patterns. In order to do this within operating costs, representative three-day case studies will be combined. One might conclude, the simplification of the model to sulphur species only and the use of selected case studies suggests that the complex model is not a viable approach for deriving information necessary for policy analysis at this time. On the other hand, Lagrangian models now are producing seasonal and annual averages of concentrations in deposition. The use of complex models, rather than the available Lagrangian models, might be construed as intentional in order to provide a three-year hiatus in the policy development area. The Eulerian products cannot be expected much before 1991. (See page 4-67, section 4.6.4.)

The report suggests that "representative three day case studies" can be combined to produce seasonal averages" and thereby reduce the cost of running the RADM. This is a dubious approach. (See page 4-67, section 4.6.4.)

This section emphasizes convective storms. There are still many problems to be solved before stratiform precipitation can be properly modelled. (See page 4-70, section 4.7.3.)

The requirement to undertake diagnostic analysis of observed meteorology has been addressed with the ADOM model. The NAPAP would benefit from reference to that model. (See page 4-75, section 4.8.3.)

CHAPTER 5

Acidic Deposition and its Gaseous Precursors

General

The authors of this chapter have done a thorough job although there are several points which require comment.

The discussion on the relative contributions of N and S compounds to atmospheric acidity is not comprehensive.

This is an excellent summary of the current knowledge of regional scale air concentrations and wet deposition measurements, together with estimates of dry deposition.

There is a major omission in the section relating to the chemistry of snowpack (as distinct from snowfall) and its implication to spring runoff. This process is of particular importance in New England and the Minnesota-Wisconsin-Michigan area.

It is critical that future assessments should address specific policy issues and summarize the state of science in specific areas. It is too bad that the present document does neither. (See page 5-113,, section 5.7.11.)

Specifics

The evidence for "a small decrease of about 10% in the average concentration" of NO_2 is tenuous. (See page 5-18, section 5.2.3.2.)

The atmospheric hydrogen peroxide data, H_2O_2 , is likely less reliable than suggested in the report.

The synopsis omits reference to the wet sulphate deposition loading in kg/ha/yr. In some areas the deposition is greater than 30 kg/ha/yr (see page 5.1, see figures 3-33 and 3-38). The loading might be considered the most important parameter of long-term stress on the environment. Why was it not mentioned in the synopsis? The same observations apply to the maximum loading of 20 kg/ha/yr in some areas for nitrate. (See figure 5.3.4.)

The switch in site type from regional to urban and going from sub-annual temporal patterns to longer term trends is not scientifically rigorous. (See section 5.3.)

The description of the APIOS network is poor: number of sites and locations not correct (Figure 5.4), description incorrect (see page 5-97, section 5.4.1.1), laboratories incorrectly described (see page 5-38, section 5.3.1.2.), Ontario deposition patterns based on old data, and length of data set (7 years) (see page 5-7, section 5.2.1.5.).

The text does not refer to the use of double sampling to estimate precision. This is a very important technique. (See page 5-34, section 5.3.)

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The Kriging approach used raises some questions. It does not seem to follow the model described by Finkelstein and, hence, there are some doubts about the results, especially in regions with low density of sites. (See page 5-41, section 5.3.2.)

For the 1980-84 composite maps and the composite winter and summer wet deposition maps, the values obtained are questionable in those regions where few data were available for 1980 and 1981. There would be high uncertainty associated with these data using the Kriging techniques. The results should be approximately correct in regions with high density of sites for all five years. (See section 5.3.2.2.)

Point #2 in Section 5.3.2.1. refers to several sites scattered about southern Ontario with pH's below 4.2. Why are these sites not included in the 4.2 contour on the map (figure 5-32)? Similarly, point #3 refers to five other sites, mostly in southern Ontario, which have sulphate depositions in excess of 40 kg/ha/yr. Why does the contour on the map (figure 5-3) not show these sites? (See page 5-41, section 5.3.2.1.)

Calcium deposition at Campbellford, Ontario is quoted at 54 kg/ha/yr. This is an error. The value is 5.4 kg/ha/yr. (See page 5-42, section 5.3.2.1.)

Figure B should be labelled 1984 'Summer', not 'Winter'. (See page 5-56, section 5.3.2.3.)

The discussion of temporal patterns of wet deposition should include reference to the major event in southern Ontario (August-September 1983, 8 days) when 28% of the annual sulphate input was deposited. (See page 5-72, section 5.3.3.)

There are two sources of uncertainty in the method used to calculate the results. These uncertainties, which are not discussed, are:

- a. the consequence of missing data in the calculation of monthly precipitation weighted mean values; and
- b. the fact that for some sites, 48% of the monthly values were missing.

(See page 5-73, section 5.3.3.2.)

The reference to total precipitation in Figure 5-51 does not seem to be correct. Should the reference be to Figure 5-58? (See page 5-79, section 5.3.3.2.)

It is not clear what the urban versus rural contrasts are supposed to demonstrate. Are we not discussing regional and continental scale pollution? (See page 5-85, section 5.3.4.)

The report states that natural sulphur emissions are likely to be larger in the eastern United States than in those areas in which the remote sites are located. What is the justification for this statement? (See page 5-96, section 5.3.6.1.)

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The discussion on dry deposition monitoring could be strengthened with discussion of the work by Barrie and Sirois (1986, J. WASP). (See page 5-100, section 5.4.1.3.)

The APN (Air Precipitation Network Network site at Montmorency is incorrectly identified as an APIOS (Acid precipitation in Ontario Study) site. (See page 5-101, figure 5-69.)

The evidence for high total SO_4 deposition in Ontario is stronger than acknowledged. (See page 5-103, Section 5.5)

The averaging period for the APN data is given as "1979-1983" and should be "1979-1982". (See page 5-104, figure 5-70.)

It is not clear why the use of Nipher shields causes U.S. deposition amounts to be biased high. (See page 5-108, section 5.6.2.1.)

CHAPTER 6

Effects on Agricultural Crops

General

This section presents a fairly good representation of the scientific literature. The discussion, however, concentrates on only a few species and a limited number of cultivars.

There seems to be no reference to studies which examine qualitative changes in agricultural produce while yield and injury symptoms are discussed extensively.

The consequences of dry deposition upon most of the crops discussed are not considered.

CHAPTER 7

Effects on Forests

General

The tone of the document suggests that natural ecosystems will not crash in the next few years under current conditions and therefore the situation is acceptable. The report dismisses the present damage in the forest environment.

The impact on plantation forests is downplayed since the soils can be limed and fertilized. There is no indication of the cost of such undertakings.

The report is fairly thorough in describing the important forest literature pertaining to the acid rain problem in the United States. The major criticisms of the report itself relate more to the content of the program than the results of specific studies.

Specifics

The objective of the U.S. program is limited since it assesses "what role if any air pollutants play in the reported regional forest damages." By focusing only on reported damage, this objective does not take account of the way air pollution may influence forest productivity in the longer term. (See page 7-1, section 7.1.)

The approach described here gives cause for concern since it suggests that a forest system can be taken into the laboratory and tested to determine whether a certain pollutant will give a field observed response. This notion is naive and does not permit studies at the stand level or work on second order effects or indirect effects. Throughout the document reference is made to secondary and natural factors. The program supports studies on the influence of environmental factors, other than air pollutants, on the upper elevation forests and attempts to examine tree responses to the interaction between air pollution and factors such as climate, insects, disease, etc. How these studies relate to the presented approach indicated on page 11 is unknown. (See page 7-11, section 7.1.6.)

In the discussion of the Pine Barrens work, the author diminishes the field observation of reduced tree growth by citing a laboratory study and indicates it was limited in scope. This is not logical. (See page 7-20, section 7.2.5.)

The document addresses the question of whether it is possible to duplicate tree responses using chamber fumigations by certain pollutants and concludes "extrapolation of seedling results to mature trees and to regional forests is not reliable at this time". One must conclude that while the work being carried out will provide a great deal of information on seedlings, it will not answer the questions posed unless mature trees are studied. (See page 7-47, section 7.6.)

It is stated that surviving trees have recovered. This is not correct. Sugar maple with all stages of decline exist in the Muskoka area. Severely declining trees die and are salvaged. Moderately declining trees do not recover and continue to display dieback at the crowns. In the 1985 McLaughlin (J. APCA) report it was stated that currently healthy trees had improved radial growth after the insect epidemic of 1978 subsided, but currently declining trees did not show a similar recovery in radial growth. (See page 7-20, section 7.2.6.)

The author indicates that soil effects from acid deposition have not been demonstrated and then cites a reference that shows soil effects. (See page 7-21, section 7.2.6.)

The maple budworm and the saddled prominent caterpillar were not involved in the Ontario decline. The insect was the forest tent caterpillar (*Malacosoma disstira*). (See page 7-21, section 7.2.6.)

The work of Kraus has in fact demonstrated that ozone accelerates foliar leaching. (See page 7-24, section 7.3.3.)

In the discussion of multiple stresses it is correctly noted that the issue is complex. The discussion, however, neglects to indicate that the issue cannot be resolved using the approach presented in the earlier section entitled "Forest Response Research". (See page 7-25, section 7.3.8.)

The section entitled "Other Problematic Hypotheses" presents a series of minor hypotheses that confuse, add little or are speculative. The report should make it clear that the program will not provide answers requested by Congress. (See page 7-25, section 7.3.9.)

The forests cannot be put in a controlled environment and, hence, one must acknowledge that the exposure-response studies discussed provide understanding but not proof of impact. (See page 7-26, section 7.4.)

Seedlings can help us understand how mature trees may respond, but the responses are not identical. In addition, studies of crops help us to understand trees but interpretation must be treated with caution. The multi-year response of trees to a single stress needs to be included as does the impact of insects and disease on natural and normal parts of the forest. (See page 7-26, section 7.4.1. and page 7-27, section 7.4.2.)

The average values of pH or any other factor are not meaningful. There is a substantial amount of literature that indicates that plants respond to extremes in the environment. (See page 7-30, section 7.4.3.2.)

The use of ppm-hr as a measure of dose has no proven validity. Studies with other air pollutants indicate that the form of the interaction between the pollutant concentration and the duration of the exposure is not linear. This type of relationship adds little to the understanding of how the plant responds. (See page 7-33, Figure 7-14.)

The pattern of ozone concentration in rural areas does not necessarily follow the classical diurnal pattern demonstrated in California. In southern Quebec the data indicates long periods (days) of high levels

(greater than 50 ppb) with little or no diurnal trend. A seven-hour daily mean would clearly be inappropriate in this case. (See page 7-35, section 7.4.4.1.)

There is no scientific consensus that tree age is not important to plant response to ozone. (See page 7-35, section 7.4.4.1.)

The section discussing gases unfortunately omitted the observation that insects preferentially select ozone treated leaves over non-treated plants. (See page 7-31, section 7.4.4.1.)

In several places throughout Chapter 7, it is noted that adverse soil changes have not been demonstrated. What is really meant is a data set has not been produced which can demonstrate a change. As a result, it is very difficult to deal with soil aspects of the problem. One must therefore question the goal of the MAPAP mission. Given the present terms of reference it may be possible to conclude that U.S. forests would not benefit from further reductions in wet and dry acid deposition. Yet the text states "There are reports of long-term soil acidification in some soils". Though the published evidence is not cited, this statement suggests that continued acid deposition could degrade the forest soils of the northeastern U.S., leading in time to a reduced productivity. On the other hand the report does cite the controversial paper by Krug and Frink (1983, Science). Why? (See page 7-41, section 7.5.)

The fact that no locations have been found where acidic deposition has been demonstrated to have an effect, is not the same as no effects have occurred. (See page 7-42, section 7.5.2.)

The Recommendations section does present an excellent description of the kind of work that has to be accomplished. Its failure is that it neglects to indicate the timeframe required - several generations of scientists, not the three years left in the program. (See page 7-52, section 7.9.)

CHAPTER 8

Effects on Aquatic Systems

General

The conclusion is drawn that "lakes will not change their acidity rapidly if deposition continues at current levels". To reach this conclusion, one must know the relationships between deposition and lake acidity. The report should take the next logical step and use these relationships to develop critical sulphate loadings.

The recovery of surface water quality in Canada is presented. The discussion makes a solid case that reduced deposition results in improved surface water alkalinity. The information is not carried into the conclusions.

There are two major omissions in this chapter:

- a. a discussion of dose-response relationships;
- b. Canadian information on acidic deposition

The omission of a discussion of dose-response relationship in this document is curious since the mandate of NAPAP is "development of dose-response functions with respect to ..." (see page 1-1, item 7).

The omission of Canadian modelling and survey results leads to an under-estimation of the severity of acidification of surface waters. For example, there are 700,000 (approximately) lakes in Eastern Canada below the 52nd parallel. Canadian surveys indicate that, of these, 16% in Quebec (72,000) and 23% in Ontario (29,000) have pH's below 6. Compare this with the total population of 33,500 lakes in the Adirondack region (11,000), Florida (9,000), and Western U.S. (13,500), combined.

The definition of "acidic" creates ambiguity. For surveys, ANC less than zero is termed acidic and is implied to be an equivalent of pH = 5.65. However, in the report, pH less than 5.0 is also defined as "acidic". Both levels are reported in the conclusions (section 8.8.1), leaving confusion for the reader as to what portion of resources are "acidic".

The conclusion section completely omits any discussion of biological effects other than fish. It fails to mention evidence of biosystem damage at pH's greater than 5.5. Both these concepts are discussed extensively in section 8.5. One wonders why this important information is not included in the conclusions.

In the text, the omission of lakes less than four hectares in area is discussed. However, the influence of this omission on the survey results is not clearly carried into the conclusions of the chapter. Thus, in section 8.3.1., the number of acidic Adirondack lakes would be more than twice the eastern lake survey estimates if small lakes were included. These small lakes represent 32% of the brook trout ponds. "Such lakes represent regionally important sport fisheries."

The significance of 9% of acidic lakes in upper Michigan is lost in the broad description of the upper midwest.

The conclusion that acidic lakes in Florida "may be largely related to land use practices" is not supported by any analyses contained in the text.

The results from examination of acidification of streams is not carried into the conclusions. The text (section 8.3.3) is misleading in that it considers only the southern Blue Ridge province. Figure 8-13 indicates that about 14% of the streams in the Adirondacks have a pH less than 5.

Specifics

The statement on trends and fish populations is inaccurate or at least subject to the definition of "low", viz.: "Overall, the number of historical trends analyses in the United States documenting loss of fish populations as a result of acidic deposition is low". The survey of Baker and Harvey would be generally considered more significant. (See page 8-73, section 8.8.2.4).

The discussion of responses of surface water sulphate to ANC does not examine the significance of the available information, even that contained in the text. We read "if sulphate has caused reduction in ANC in some aquatic systems, it is the amount of ANC lost and not the present ANC concentration that would be expected to be related to anthropogenic sulphate input." This is the point where cause-effect could be made highly evident. (See page 8-19, section 8.3.1.1. and page 8-73, section 8.8.3.)

The EPRI's PARLOUR project shows evidence that the pH values of some lakes in the Adirondacks have declined in recent years, contrary to the steady state conclusion in the report (see page 8-74, section 8.8.4.)

The report states that there are large numbers of lakes between 0-50 $\mu\text{eq/l}$ alkalinity and that the acid neutralizing capacity of soils is not well understood. This information suggests that the capability of predicting further acidification is poor. How can the authors then conclude "in the Northeast, that the surface water chemistry of most watersheds is at or near steady state with respect to sulphur deposition."? (See page 8-84, section 8.8.4.1.)

Even if there were chemical equilibrium, biological lags could prolong biological equilibria for years to decades as reported by Canadian researchers comparing chemical and biological responses (See page 8-74, section 8.9.2.)

CHAPTER 9

Effects on Materials

This chapter has not been reviewed.

CHAPTER 10

Effects of Acidic Deposition and Associated Gaseous Pollutants on Human Health and Visibility

Out of the 336 references at the end of the chapter, only 12 refer directly to visibility. The report on visibility by Pueschel under the WMO Environmental Pollution Monitoring Program is more complete.

Health

NAPAP has no research activities in human health effects of acidic deposition. NAPAP's lack of internal expertise in this area is particularly evident in the reviews of epidemiological and controlled human exposure studies. There is a lack of understanding of the fundamental concepts and methods used in assessing human health effects and, consequently, the validity of the evaluation and recommendations can be questioned.

It is unfortunate that the expertise within EPA was not appropriately used and that criteria documents such as the ones on ozone, SO_2 and particulates were not used as the basis for the health assessment. Of course, the assessment does make extensive reference to portions of these documents, but a thoughtful interpretation of the data and the information developed by EPA is not evident.

The discussion on ambient acidic aerosol exposures and controlled exposure (chamber) studies does not fully explore the possible link between exposure and health effects. For example, the levels used in the chamber study are not excessively higher than ambient levels, particularly when an effort is made to convert the ambient air level (milligrams/metre³/air) to delivered dose (milligrams/kilogram/hr). Several research programs in the U.S. and Canada should have been mentioned since they indicate that there is sufficient concern to warrant further elucidation of the issues.

With respect to indirect health effects, in Canada a 1981 report indicates that 13% of Canadians do not receive treated water. At the moment, a study is underway to determine the number of people who use wells and who live in acid sensitive/impacted areas. Assuming a similar proportion in the United States, this means that a sizeable number of people may be affected by unacceptably high levels of contaminants due to corrosive water supplies. (See page 10-55, section 10.3.4.3).

Visibility

Some conclusions in Section 10.5.3, Visibility Effects, and included in the Executive Summary, are inconsistent with the text of Chapter 10 and the figures, for example:

- a. "A significant increase in visibility has been observed since 1970 for the industrial States north of the Ohio River, including Indiana, Michigan, Ohio, Pennsylvania and New York. This increase is most pronounced during the winter season". (See page 1-35, and section 10.5.3.)

- 28 -

Compare with:

"For the Ohio River basin and Indiana, the first quarter haziness [i.e. winter season] has remained high over the 1948-1983 time period (Figure 10-11b). The summertime haze on the other hand shows an increasing trend until the 1970's, followed by a significant decline since 1977 which exceeds the standard deviation among the stations". (See page 10-60.) [The first conclusion above is OK only in reference to figure 10-11a.]

- b. Executive summary and Section 10.5.3. "Summer visual range in rural areas is approximately 20-30 km in the East and 75-200 km in the West"...

Compare with:

Figure 10-10 states that summer haziness is above $300 \times 10^{-6} \text{ m}^{-1}$ for most of the Eastern U.S. This corresponds using Koschmeider's formula to less than 13 km visual range for the summer season. This is a factor of 2-3 discrepancy.

The examination of haze and emission trends includes the following comment "annual averages for sulphur emissions and coefficient of haze between 1950 and 1980 for the southeast appear to be positively coordinated, however, other sources (such as organic carbon) which contribute to haze could also be correlated with changes in visibility." To put the matter in perspective, one might refer to the paper by Wolf Morrissey and Kelly, (General Motors Report 4448ENV#159, 1983) which states "for example, we estimate that during the summer, SO_4 and absorbed water account for 78% of the light extinction in the Blue Ridge Mountains (Foreman, Wolff, Kelly, J. APCA 31, 1074, 1981)". (See page 10-67, section 10.4.5.)

For 2% of the time, summer visibilities are reduced by pollution to the point where instrument flight rules must be followed. This places a particular requirement upon small private aircraft usage. The associated economic implications should be calculable. (See page 10-68, section 10.4.6.)

APPENDIX 1

LIST OF REVIEWERS

T. Brydges	Environment Canada
H. Martin	Environment Canada

EMISSION AND CONTROLS

B. Blakeman	Environment Canada
D. Draper	Environment Canada
A. Hazra	Environment Canada
V. Shantora	Environment Canada
P. Vena	Environment Canada

ATMOSPHERIC PROCESSES

V. Chan	Environment Ontario
G. Isaac	Environment Canada
M. Gleason	Environment Canada
M. Lucio	Environment Ontario
H. Neumann	Environment Canada
M. Phillips	Environment Canada
K. Peckett	Environment Canada
N. Reid	Environment Ontario
A. Sirvis	Environment Canada
R. Schenckauer	Environment Canada
P. Sumner	Environment Canada
E. Veldner	Environment Canada

EFFECTSForests and Crops

P. Addison	Agriculture Canada
A. Egan	Environment Ontario
S. Lissner	Environment Ontario
U. McIlvann	Environment Ontario
D. McLaughlin	Environment Ontario
F. Rennie	Agriculture Canada

Aquatics

V. Cairns	Fisheries and Oceans
P. Elder	Environment Canada
D. Gouin	Environnement Quebec
K. Minns	Fisheries and Oceans
A. Stasko	Fisheries and Oceans
L. Talbot	Environnement Quebec

Health

C. Franklin	Health and Welfare
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Visibility

B. Wall	Environment Canada
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COMMENTS ON THE EXECUTIVE SUMMARYEffects on Materials

The section on Effects on Materials, considering that it is directed to the "non-technical" decision makers and the general public, is inadequate as a concise evaluation of what is being done, why it is being done nor what new research is required to achieve the final objective; that of assessing the economic and other effects of acid deposition. (See page 1-33, section 1.3.1.0.)

The discussion of steel, stone and coatings is too general and fails to state that existing program will not provide the answers to questions the program was designed for. (See page 1-33, section 1.3.10.1, 1.3.10.2, 1.3.10.3.)

The section describing Assessment Needs should be the lead section qualifying all else that is said later. (See page 1-33, section 1.3.10.4.)

CHAPTER 9Effects on MaterialsGeneral

This report is a mixture of state-of-the-art review and a description of the NAPAP Program of Research. It is not clear which of these is the main objective of this report. The priorities set for the NAPAP Program do not seem to correspond to the indicated need for the information.

The report outline seven areas of research that need to be carried out in order that the overall objective can be achieved, giving the impression that these areas are under study, but in fact most of these areas are not included in the Program. This report fails to state clearly what aspects of the overall research needs are under study nor does it point out the consequences of the "missing" information. For example, it is discussed that great variability in time-of-wetness, pollution deposition, etc., is to be expected on real structures, but it is not stated that this information is essential if current data from test sites and laboratory experiments is to be used for estimating losses in practice. Furthermore, no work is in progress or planned in the immediate future to provide the necessary information.

The part of the report giving the state-of-the-art contains much general information that is well known and documented and, as such, is redundant.

Consideration might have been given to the recommendations for research needs given in Sereda, P.J., 1986. EFFECTS ON MAN-MADE STRUCTURES. This publication is referenced on page 9-40. The key recommendation is

the selection and use of a network of suitable buildings in major cities to serve as sites for monitoring levels of pollution and microclimatic factors.

Sections 9.4.2, 9.4.3, 9.4.5 and Table 9-10 make a compelling case for the need to measure various environmental and material parameters on actual buildings in urban areas in order that some quantitative understanding of the influence of size, shape, orientation, location on a building, etc., can be achieved to enable the use of data being derived at exposure sites and the laboratory.

Specifics

The relationship in Figure 9.1 is too simplistic and as such not useful - for example; in the case of Cortan steel the non-acidic deposition damage function can be higher than the one representing the polluted environment. (See page 9-2.)

In section 9.1.2, four factors are given but these do not define the complexity of the system; for example item 3 is misleading because it does not include factors such as time-of-wetness, pollution fluxes, etc., etc. (See page 9-2.)

The listing in Table 9.1 ignores the fact that most reactions in corrosion and deterioration involve two or more species, vary with the concentration and involve synergistic effects. Therefore such listing has little merit. (See page 93, section 9.1.2.)

Table 9.2 presents an Index of Material Significance. Previous estimates placed protective coatings - zinc and paint, at the top of such ratings not cement and concrete. Brick should be very low. Plastics are seriously affected by ozone and should not be left out as suggested in the text. (See page 9.3, section 9.1.2.)

The information contained in Table 9.3 constitutes generalizations and is of little use. This is information that is common knowledge and has been documented in many reports. (See page 9.4, section 9.1.2.)

Some detail in section 9.2.3 is hardly necessary in a report of this nature, for example, the discussion of cycle producing iron oxyhydroxide.

Recent results presented by Johansson, Linquist and Mangio, at a Symposium on Air Pollution and Conservation, Rome Oct. 15-17, 1986, confirm the synergistic effect of NO_2 and SO_2 where 3.1 ppm NO_2 with 1.6 ppm SO_2 increased deterioration of marble 4-fold and travertine by 10-fold. This type of information strongly suggests that realistic data of stone deterioration must be obtained from studies on buildings in urban areas where the complex set of environmental parameters can be realized and not from exposure sites that may be located in an environment lacking in one or more critical parameters. (See page 9-10, section 9.2.3.1, and also page 9-15, 9-16, section 9.2.4.2, where it is stated "Those studies show the difficulty of attributing stone

concentration and periodicity of environmental factors involved in corrosion and weathering processes". Having recognized this fact, it follows that surveys of materials on existing buildings in various parts of the country should be a part of the NAPAP Program. Where is this kind of work occurring? (See page 9-25).

The authors recognize that before dose-response functions (derived from data obtained at exposure sites and the laboratory) can be applied to a material inventory, measurements must be made to determine the variability of deposition of pollutants, variability of the time-of-wetness and rain deposition on various buildings. However, no part of the present or future NAPAP Program is designed to provide such information. (See page 9-26, section 9.4.2.)

How can one "assume that the errors are randomly distributed" in the discussion of effects on real structures. This is a "leap of faith" - surely there must be some bases for this assumption. Surveys of materials on suitable buildings would provide some bases. (See page 9-28, section 9.4.5.)

Deposition velocities are of little value. This is why it is better to measure flux rather than deposition velocity because the concentration is also changing and must be known to get the value of flux. The question of how to measure flux on various surfaces should be an important part of the NAPAP program. (See page 9-29, section 9.4.5.1.)

The "estimate" of deposition variability should be determined on selected buildings in low and high polluted urban environments. (See page 9-30, section 9.4.5.2.)

Rain does not necessarily accelerate weathering. For example, rain washing the surface of aluminum cladding causes a decrease in the rate of corrosion by pitting. (See page 9-30, section 9.4.5.3.)

Section 9.4.6. summarizes accurately the state-of-the-art and should have been the bases of the current program of research in NAPAP. It is true that the "assessment of damage to structures in real-world exposures [is] an uncertain endeavor" (See page 9-31, section 9.4.6.) When one examines Table 9-10, and notes the variability associated with estimates of various factors ranging from 2 to 10 (most of which are uncertain), what is needed is measurements not refining of estimates.

Section 9.4.6., Summary, closes with the statement "Given appropriate focus, the uncertainties could be reduced within the remaining NAPAP timeframe through application of theoretical and experimental approaches from relevant disciplines." This statement means little unless it is another "leap of faith". (See page 9-32.)

It seems that the application to real structures in the future program has been assigned too low a priority. This work is vital to enable all the other research results to be useable. This work should be started now and adequate resources assigned to it. (See page 9.3.3, section 9.7.6.)

deterioration to a single environmental factor such as sulfur dioxide. Studies of many environmental factors in combination are needed to assess their individual and synergistic effects.")

Further work in chambers must take account of other factors. These chamber experiments, studying chemical processes should be supplemented by tests that involve physical processes such as freeze-thaw cycles, after certain periods of chemical exposure. Changes in pore sizes and presence of certain salts (ions) will change the resistance of the porous material to freezing effects. These experiments must include multiple parameters as discussed in the previous point. (See page 9-18, section 9.2.4.3.)

The discussion of points in the dose-response context is not complete. (See page 9-20, section 9.2.5.2.) High permeability of paints to SO_2 is mentioned but not discussed from the standpoint of this possibly having a large effect on bonding and accelerating moisture transfer because of lower vapour pressure at the interface. This evidence is justification for research into this aspect. This review section on paints omits some important references such as Ashton, 1983 and 1984. (Ashton, H.E. 1984 Clear Finishes for Wood - An example of one Approach to Predicting Performance. In; Organic Coatings Science and Technology, G.N. Parfitt and A.V. Patsis, Eds. Marcel Dekker Inc., pp. 479-506. Ashton, H.E. 1983. Evaluating the Performance of Organic Coatings and Building Materials. In; Performance of Organic Coatings, ASTM STP 781, pp. 67-85.)

It is not explained why paint was tested on stainless steel. Because paint is never used on stainless steel, the results cannot be used as an indication of performance of these paints in the particular environments. (See page 9-21, section 9.2.5.3)

The research plan for coatings must consider interfacial bonds. It is generally agreed that performance of paint is related to the substrate and the interfacial bond with the paint, and for this reason studies of the effects of acid deposition on paint must include the effect on the interfacial bond. Such studies should also include measurements of residual stress in paint coatings. (See page 9-21, section 9.2.5.3.)

Section 9.3.1 discussed the Construction Materials Inventory. This kind of inventory is not very useful unless the proportion of material per building is further subdivided according to appropriate "severity" rating of the particular exposure; -roof vs wall (top, middle or bottom of building). This type of inventory must follow a survey to provide a definition of the "severity" variable for any one building - which most likely, will depend on construction type (classification such as Table 9.6, 9.7, etc.) and a host of meteorological factors. It may be argued that an inventory of materials at "greatest" risk is of real importance. (See page 9-22, section 9.3.1.)

Section 9.4 on Application to Real Structures is the most important section. It is stated that; "These studies indicate that there is sufficient variation in the deterioration of metals, coatings and masonry materials within urban areas to warrant a closer look at the occurrence

APPENDIX II

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

722 JACKSON PLACE, N.W.
WASHINGTON, D.C. 20503
202/305-5771



September 16, 1988



The Honorable James H. Scheuer
Chairman, Subcommittee on Natural Resources,
Agriculture Research and Environment
Committee on Space, Science and Technology
U.S. House of Representatives
Washington, D.C. 20515



Dear Mr. Chairman:



On behalf of the National Acid Precipitation Assessment Program, I am pleased to transmit NAPAP's analysis of critiques received regarding the the 1987 Interim Assessment and its Executive Summary. This analysis responds to your request conveyed during a Subcommittee hearing on April 27, 1988 and further specified in your letter of June 2, 1988.



As you have requested, NAPAP has summarized the critiques received, analyzed them in light of available information (including studies not available when the Interim Assessment was written), and indicated how the critiques will be taken into consideration in the preparation of NAPAP's 1989 and 1990 assessment reports. Further, this document provides information you requested concerning the range of likely effects, the certainty with which statements are made, and the quality of available data.



The enclosed report constitutes an element of the continuing dialog aimed at providing the best possible technical information on acidic deposition causes, effects and control approaches, to assist in the development of national policy on these issues. Some information in this report also appears in a separate analysis which deals exclusively with the critiques expressed by the Canadian Government. A copy of that analysis, requested by Congressman Dingell, was sent to you on August 16. NAPAP is providing a copy of the enclosed report to all of the commentators listed in Table 1 of the analysis, and to all members of the Subcommittee.

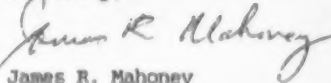


Honorable James H. Scheuer

2

NAPAP has prepared an internal review draft of its comprehensive Assessment Plan, describing the information to be covered in NAPAP's 1989 and 1990 reports. The Interagency review schedule has been extended to allow additional consideration of the draft Plan, and public release of the Plan is scheduled for mid-October. A public meeting to receive comments on the Plan will be held approximately four to six weeks after its publication. NAPAP would be pleased to brief Subcommittee members or staff on the Plan at your convenience upon its publication.

Sincerely,



James R. Mahoney
Director

Enclosure

cc: Members of the Subcommittee
NAPAP Joint Chairs Council
Honorable John D. Dingell

NAPAP ANALYSIS
OF THE
CRITIQUES
OF NAPAP's 1987
INTERIM ASSESSMENT

SEPTEMBER, 1988

NAPAP'S ANALYSIS OF THE CRITIQUES
OF NAPAP'S 1987 INTERIM ASSESSMENT

INTRODUCTION

This analysis addresses critiques of the National Acid Precipitation Assessment Program's (NAPAP) Interim Assessment Report. The sources of the critiques addressed are identified in Table 1. This list includes the major technical critiques provided directly to NAPAP or which have been presented in Congressional testimony. This document was prepared at the request of Congressman James H. Scheuer as a result of hearings held on April 27, 1988 before the Subcommittee on Natural Resources, Agriculture Research, and Environment of the Committee on Science, Space and Technology, U.S. House of Representatives. This analysis was designed to respond to the specific requests of Congressman Scheuer in his June 2, 1988 letter to the NAPAP Director.

The scientific information presented in the Interim Assessment reflects the state of knowledge at the time of its preparation. Continuing research, and expanded discussion of the available scientific information, will significantly improve the usefulness of the technical information available to policy officials by the time NAPAP issues its assessment reports in 1990. This analysis focuses on the technical issues raised in the critiques received by NAPAP; it does not respond to generalized critical statements, nor to policy statements, which are outside of NAPAP's responsibility.

For each principal issue category, NAPAP's discussion is divided into as many as five parts:

The first part is a summary statement of each critique, including quotations from the critics. In some instances several critics raised the same issue, and in those instances all critics are not specifically identified. However, Table 2 lists all of the critics for each issue. The summary statements were prepared by NAPAP and focus on technical comments.

The second part is NAPAP's analysis of the technical issues raised by the critics. This section reviews the Executive Summary and other parts of the Interim Assessment in terms directly responsive to the critiques. In many instances, this section includes a discussion of data quality and uncertainties. New work is discussed as appropriate.

The third part is a statement of uncertainty and, where appropriate, data quality. These statements are provided as

a separate item from the analysis for aquatics and some other areas. In other instances the discussion of uncertainty is merged with the analysis section.

The fourth section includes a brief statement of those new results whose analysis was requested by Congressman Scheuer. NAPAP's 1990 Assessment will include a comprehensive literature review, and the 1988 and 1989 Annual Reports will list the hundreds of NAPAP-sponsored publications that are currently being produced. The Annual Reports will also report on research highlights.

The fifth and final section describes NAPAP's plans for future consideration of issues raised. This section describes the uncertainty expected in the 1990 Assessment. Future action includes both continuing research and the development of NAPAP's 1990 Integrated Assessment. The plan for the 1990 Assessment, to be released in October 1988, will provide considerable detail about how NAPAP will define and address these and other issues.

This analysis is one element in the process of completing NAPAP's 1990 Integrated Assessment. The Assessment Plan will be published in October 1988, and NAPAP will hold a public meeting to receive comments on the plan in November 1988. The Assessment Plan will define the effects being examined; identify the specific questions being addressed; identify and discuss analysis methods, assumptions, and data bases to be used; define the scientific confidence levels expected; and identify the analyses of alternative control approaches to be documented. After consideration of comments, NAPAP will issue a revised plan in January 1989, and will follow this plan in preparing its integrated findings and recommendations.

Table 1

COMMENTS ON THE INTERIM ASSESSMENT ANALYZED
(in chronological order)

- | | |
|----------------------|--|
| 1. NRDC | - News Release September 6, 1987 from the Natural Resources Defense Council. |
| 2. Schindler 1 | - October 28, 1987 letter from Dr. David W. Schindler to Dr. Gene E. Likens. |
| 3. Galloway | - November 12, 1987 memo from Dr. James Galloway to Dr. Gene E. Likens. |
| 4. Likens | - November 12, 1987 letter from Dr. Gene E. Likens to Congressman John D. Dingell. |
| 5. Canadian Critique | - January 6, 1988 Letter from Canadian Environment Minister McMillan to EPA Administrator Thomas |
| 6. Sikorski | - January 9, 1988 letter from Congressman Gerry Sikorski to EPA Administrator Thomas. |
| 7. Schindler 2 | - January 22, 1988 letter from Dr. David W. Schindler to Congressman John D. Dingell. |
| 8. Scheuer 1 | - May 10 Draft Transcript of April 27 Hearing on the NAPAP Interim Assessment. |
| 9. Scheuer 2 | - June 2, 1988 letter to NAPAP Director James R. Mahoney. |

Table 2

GUIDE TO ANALYSIS OF COMMENTS RECEIVED

Source of Comments¹

	1	2	3	4	5	6	7	8	9
Location of Analysis ²									
INTRODUCTION									X
AQUATIC EFFECTS:									
1.1	X	X	X	X	X	X	X	X	
1.2	X					X			
1.3	X				X				
1.4	X		X	X		X		X	
1.5	X							X	
2	X	X	X	X	X		X	X	
3	X				X			X	
FORESTS AND CROPS:									
4.1					X				
4.2					X		X		
4.3				X					
4.4								X	
4.5					X				
4.6					X				
4.7					X		X		
4.8				X					

¹ The numbers refer to comments whose origin is specified in Table 1.

² The numbers in the column below refer to the portions of the text identified in the Table of Contents.

Table 2 (cont.)

GUIDE TO ANALYSIS OF COMMENTS RECEIVED

Location of Analysis ⁴	Source of Comments ³								
	1	2	3	4	5	6	7	8	9
HEALTH					X	X			
VISIBILITY					X	X			
MATERIALS					X	X			
EMISSIONS:									
8.1	X			X	X				
8.2					X				
8.3	X				X	X		X	
8.4	X								
SOURCE- RECEPTOR MODELS:									
9.1					X				
9.2					X				
9.3					X			X	
9.4					X				
9.5					X				
DEPOSITION				X					
ECONOMICS				X				X	

³ The numbers refer to comments whose origin is specified in Table 1.

⁴ The numbers in the column below refer to the portions of the text identified in the Table of Contents.

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AQUATIC EFFECTS

A dominant uncertainty in the assessment of potential aquatic damage arising from acidic deposition is the interpretation of results from individual intensive studies on individual lakes, streams or organisms and their extrapolation to the population of surface waters or organisms. Intensive research at single sites has shown that a variety of processes affect the acidity of surface waters. However, the question has remained as to how important any of these processes are in the population of surface waters. The aquatic effects research program has been designed to evaluate the regional importance of acidic precipitation with respect to aquatic resources. In the following three sections the program designs for extrapolation are discussed and the shortcomings associated with the attempt to generalize from smaller scales are identified. These discussions are framed to respond to the critiques of the Interim Assessment.

1. THE EXTENT OF ACIDIC SURFACE WATERS

This section focuses on concerns raised about the chemistry of surface waters and their biological status. The next section focuses on steady state of surface waters and on change.

1.1 pH 5.0 as a Surface Water "Standard" and Biological Responses

Comments:

Virtually every critic of the Interim Assessment listed in Table 1 has suggested that the use of pH 5.0 as an indicator of lake damage "unreasonably minimize[s] the seriousness and geographic extent of the (acid rain) problem" (McMillan, 1988, p. 2). Dr. Schindler (1987) asserts that "perhaps the most serious misrepresentation [in the Interim Assessment] is to use pH 5.0 as a threshold for considering lakes to be damaged." It is suggested that a pH of 6.0 would be more appropriate, since this is the level at which "serious damage begins to occur in lakes." (McMillan, 1988, p. 2); and "the fact that biological damage begins at pH 6 is irrefutable." (Schindler, 1987) Congressman Scheuer also argued against the use of pH 5, noting, "The Executive Summary defined acid lakes as those lakes with pH's of 5.0 or less, when going to 6 or less, which defines many of those lakes, would have given us ten times the number of lakes at risk." (U.S. Congress, 1988, p. 63) The Canadian critique asserts that effects are widespread and very serious, cites the main body of the report and faults the Executive Summary for stating that only "some" rather than "numerous" surface waters have been "acidified". Dr. Likens also finds that "Statements like, acidified lakes '... represent a small fraction of the surface waters in the United States ..., are misleading and minimize the impact in affected areas."

Analysis:

Presentation of data on the fraction of surface waters above or below any pH value describes only the current status of water bodies. Such data alone cannot define the extent of damage. Estimates of change must be integrated with an evaluation of status for assessing damage or the seriousness of the problem. The next section discusses our ability to estimate and analyze change.

Consideration of the selection of pH 5.0 to discuss the status and extent of aquatic impacts requires the definition of several terms. In the Interim Assessment, an "acidic surface water" is defined as one with a pH below 5.0. (NAPAP, 1987, pp. I-30 and 8-2). A recent Norwegian publication (Norwegian State Pollution Control Authority, 1987) used a pH level of 5.0 as a reference value in the same manner as the Interim Assessment. This use of a single pH level reflects only the current status of a water body, and in the absence of other information, is inherently incapable of providing estimates of change or damage. An "acidified surface water" is one that has lost some acid neutralizing capacity (ANC), even a small, biologically insignificant amount. Thus, "acidification" is a process that may or may not result in acidic surface waters and may or may not be related to acid deposition. Surface water surveys can determine the extent of waters with specific chemical characteristics. However a thorough understanding of the processes of acidification is required to estimate how the extent of surface water acidity has changed or will change given various levels of deposition. Estimates of change are more useful than estimates of surface water status for developing estimates of damage.

Loss of any ANC, even a small amount, is by definition "acidification". Acidification would not always be expected to produce a deleterious biological effect, because it may not necessarily be accompanied by a biologically relevant change in pH. Therefore, while recognizing that loss of ANC constitutes acidification, the Interim Assessment also recognizes that loss of ANC does not necessarily produce changes in biologically relevant chemistry.

The Interim Assessment provides population estimates of surface waters at selected pH or ANC values. A pH of 5.0 was selected as one reference value in the Executive Summary, and information on the extent of waters at other values is also provided in the Executive Summary and more extensively in Chapter 8. The inclusion of tables provided in the chapter (e.g., Tables 8-3 and 8-4; pp. 8-20, 8-21) in the Executive Summary might have prevented misunderstanding about NAPAP's descriptive summary of lake chemistry. These tables indicate that using a higher reference pH (a pH of 6 rather than 5) would lead to a two- to five-fold increase in the percentage of lakes below the increased pH value. The estimated number of lakes in the target areas changed from about 3 percent (pH < 5) to 13 percent (pH < 6) in the Northeast, 2 percent to 10 percent, respectively, in the Upper Midwest and 12 percent to 33 percent, respectively, in Florida. The Interim Assessment also provided estimates of both lake numbers and areas of acidic, low-pH and low-ANC lakes. The Interim Assessment did not provide data on the number of lakes that have been acidified because such estimates were not available.

It is widely accepted, and shown in Chapter 8 (Section 8.5, especially pp. 8-60 to 8-65), that if a lake or stream is at a pH of 5.0 or below, then many desirable fish and other organisms do not survive. (There are some exceptions to this general observation where desirable fish appear to be viable at pH below 5.0. These exceptions appear to include surface waters with high concentrations of organic material and may also include lakes with relatively low concentrations of aluminum. Some Florida lakes, for example, have pH < 5.0 and yet have viable, reproducing fish populations apparently because aluminum concentrations are quite low.) It is also widely accepted, and clearly stated in the Interim Assessment and its Executive Summary (pp. I-31 and I-50), that biological changes have been demonstrated at pH values 5.5. Whereas changes in biology are noted as pH and other chemical constituents change, it should not be assumed that all variations in aquatic chemistry and biology are due to acidic deposition, or that chemical and biological variability is synonymous with damage. The validity of making a general statement that serious damage begins to occur at pH 6.0 requires a detailed assessment of the effects of acidic deposition on aquatic chemistry and biology. Other factors must be considered in these assessments. Such an assessment is planned for the NAPAP 1990 Integrated Assessment.

The Interim Assessment Report can be interpreted as suggesting that the percentage of acidic lakes in the United States is small. This clearly does not mean that some locations such as the southwestern Adirondacks have a small percentage of acidic waters. (See for example NAPAP, 1987, pp. 1-31 and 8-23 through 8-29 and 8-35 through 8-36).

In summary, the Interim Assessment states that biological responses can occur at pH levels above 5.5. A pH of 5.0 is used to inventory "acidic" lakes; i.e., reflecting the status of lakes rather than to suggest any implication about the source of the acidity, the date of its origin, or the presence or absence of biological change at other pH levels. These factors will be evaluated by the Direct/Delayed Response Project and other studies which will be presented in the 1990 Assessment.

Uncertainty:

There is uncertainty associated with estimates of lakes with pH values less than some specific criterion value such as pH 5.0, 5.5 or 6.0. This uncertainty includes sampling error, analytical error, natural variability and the original selection of the target population. This statistical uncertainty is discussed fully in the reports of the surface water surveys (Landers et al; 1986, and Linthurst et al; 1986). An example of the depiction of this uncertainty is shown in Fig. 8-7 (NAPAP, 1987) which shows the 95 percent upper confidence limit for pH. This uncertainty, for example, could increase the number of Adirondack lakes with pH < 5.0 from 128 to 179 or increase the area from 1962 ha to 2977 ha. This uncertainty also could result in a corresponding decrease in the estimated number/area of lakes with pH < 5.0. The area of greatest uncertainty, however, is what these pH values mean ecologically. Bioassays, experimentation, and field correlation represent the typical approaches used to relate chemical concentrations to biological effects. Results from bioassay and laboratory experiments, although well-defined in a controlled, confined environment, are difficult to extrapolate to a variety of lakes and

streams throughout an entire region. Natural environmental variability can confound the application of these bioassay and lab results. This same variability, in addition to biotic interactions also confounds field experiments and correlations. It is impossible to measure all the variables that might influence chemical effects on biota in the field. For example, regression equations (see for example NAPAP, 1987, Fig. 8-25) relating the effects of pH on brown trout species are different in the Adirondacks and Ontario because other unmeasured variables are probably important. This type of uncertainty is unlikely to be completely resolved by 1990.

1.2 Alkalinity versus pH

Comments:

Congressman Sikorski questioned why alkalinity was not used as an indicator of surface water sensitivity to acidic deposition. He asserted that alkalinity is a measure of the buffering capacity of surface waters and as such might be a better indicator of future damage than pH. pH, in fact, might underestimate future potential damage.

Analysis:

pH was used rather than alkalinity because pH is more biologically meaningful than ANC. However, from a chemical perspective the two variables are functionally related. Alkalinity or acid neutralizing capacity (ANC) is one measure of the buffering capacity of a surface water. This measure, however, should not be equated with sensitivity to acidic deposition. Low ANC is a necessary but not a sufficient condition for sensitivity. (NAPAP, 1987, pp. 8-10 and 8-11) If the buffering capacity is replenished by the watershed or lake as rapidly as it is depleted, the system could have low alkalinity but not be sensitive to acidic deposition.

Uncertainty:

pH and ANC are functionally related (NAPAP, 1987, Fig. 8-2) but the pH and ANC values selected to indicate acidic or potentially susceptible surface waters can be quite different. For example, the percentage of Northeastern lakes with pH < 5.0 (3.4 percent) or ANC < 0 (4.6 percent) or pH < 6 (13 percent) or ANC < 50 (19.2) are similar, but not equal. About 60 percent of the northeastern lakes have an ANC < 200, which corresponds with a pH of about 7.6. This pH value is greater than any values suggested by scientists as being an "upper limit" for susceptibility to acidic deposition. The selection of one pH value or one ANC value to describe the population of surface waters susceptible to acidic deposition is not warranted. Sensitivity to acidic deposition reflects multiple attributes of systems that cannot be captured by a single value of a single variable.

1.3 Small Lakes

Comments:

Several reviewers (including NRDC, 1987; U.S. Congress, 1988; pp. 51 and

64; and RMCC, 1988) expressed concern about the decision to exclude small lakes and ponds (< 4 hectares). They claim that this biases the NAPAP analysis because such bodies of water are more prone to acidification than larger lakes. The Canadian critique suggested that the geographic extent of surface water acidification would be significantly increased if small lakes and ponds were considered.

Analysis:

The importance of small lakes (< 4 ha) and the observation that a greater percentage of them are acidic than larger lakes in the Adirondacks is stated in Sections 8.3.1 (p. 8-16) and 8.8.1.1 (p. 8-72) of the Interim Assessment, although the cause of the acidity is not determined in most instances. The significance of these small lakes in the Adirondacks is noted both in the chapter text and in the chapter synopsis, which appears in the Executive Summary. Preliminary analyses indicate the percentage of acidic lakes in the Adirondacks might be twice as large (by including the small lakes) as estimated by using data from the surface water survey alone. Small lakes were excluded from quantitative description because accurate maps for the smaller lakes do not exist throughout the geographic domain of the Eastern Lake Survey. They do exist in some regions, including the Northeast, but their use would have been extremely labor-intensive and would have delayed the survey by at least one year. Further, the intensive work done by the Adirondack Lake Survey Corporation (ALSC) allows an examination of the chemistry and biology of the smaller lakes. It should also be noted that NAPAP estimates of lake condition exclude lakes larger than 2000 ha.

NAPAP's Aquatic Effects Task Group has a current project to compare data from the Eastern Lake Survey (ELS) and the ALSC. This project will expand the descriptions of lake population status in the 1990 Assessment, which will include an evaluation of a lower limit on lake size in some regions.

NAPAP is unaware of evidence that the geographic extent of acidic surface waters would be increased if lakes less than 4 hectares were included. Acidic lakes were estimated in every subregion in the Northeast so it is improbable the geographic extent of acidic surface waters would be increased.

1.4 Streams

Comments:

Congressman Sikorski (1988) commented that the Interim Assessment relied exclusively on the NAPAP Pilot Stream Survey and ignored other sources such as the study by Lynch and Dise (1985) on Shenandoah National Park streams. Likens expressed concern over the statement, "...no acidic lakes and streams (pH < 5.0) have been found in the Southern Blue Ridge Province..." (NAPAP, 1987, p.I-8). Dr. Galloway (1987) also noted the absence of reference to the Lynch and Dise report. The Natural Resources Defense Council noted the absence of results from the National Stream Survey (NSS) and also commented on the failure of the NSW to sample New England streams.

Analysis:

The NAPAP NSS focused on streams in the Mid-Atlantic and Southeast, where streams are the predominant aquatic resource. Streams in other regions of the U.S., such as New England, certainly are an important resource but information on surface waters had already been collected as part of the National Lake Survey. Little synoptic information was available for surface waters in the Mid-Atlantic and Southeast. The decision, therefore, was to collect synoptic information from those regions in which it was not available.

Dr. Likens correctly notes that there are acidic streams in areas of the eastern U.S. that were not discussed in the NAPAP Interim Assessment, for example, those under study by Dr. James Galloway in Shenandoah National Park and in other parts of Virginia. In fact, a new report from NAPAP's Aquatic Effects Research Program on the status of Mid-Atlantic and Southeastern streams (which examined over 400 stream reaches in 17 states) provides results which are consistent with Dr. Galloway's (unpublished) findings. These data were not available at the time the Interim Assessment was written. The absence of these data (the NSS and from Dr. Galloway's work in Virginia) from the Interim Assessment properly reflect the status of the research at the time of the document's preparation rather than any deficiency in the National Surface Water Survey (NSWS) or the Interim Assessment. Care was exercised in identifying the boundaries of the geographic areas discussed in the Interim Assessment report so that the document would not be misleading. The status of streams discussed in the NAPAP report were specifically and explicitly limited to the Southern Blue Ridge Province (SBRP) which does not include the Shenandoah National Park. The status of SBRP streams was accurately reported.

The streams cited by Dr. Galloway in his letter to Dr. Likens are located in the Valley and Ridge Province which is about 200 miles north of the SBRP. At the time of the NAPAP Report preparation, the SBRP was the only area in which the NSWS had completed a statistically rigorous survey of streams that allowed for population estimates. Therefore, it was appropriate that only these data and the resultant conclusions were cited in the Executive Summary of the Interim Assessment.

The Lynch and Dize report on the sensitivity of streams in the Shenandoah National Park to acidic deposition was not included in the Interim Assessment. The report documents the results of six synoptic surveys conducted on 56 streams in the Park. Several acidic streams were sampled in these surveys and during the course of the survey virtually all streams were observed to have alkalinities less than 200 ueq/l. This study noted a strong relationship between bedrock type and stream water chemistry. This study and its results will be incorporated in NAPAP State of Science documents and the 1990 Integrated Assessment.

Summary results of the National Stream Survey, which will be published in September 1988, are provided in the section "Major New Findings in Aquatic Effects" on pages 25 through 27 of this analysis.

Uncertainty:

There are a number of streams in the Northeast that originate from

headwater lakes. For these particular streams, the distribution of fall lake chemistry might reflect the distribution of fall stream chemistry, at least in the upper stream reaches. The relation of downstream chemistry to upstream chemistry and the distribution of chemistry in northeastern headwater streams is uncertain and will not be resolved by 1990. Site-specific studies on New England streams (based on non-NAPAP data) will be examined as part of the NAPAP 1990 Integrated Assessment.

1.5 Acidic Surface Waters in Canada

Comments:

The Canadian critique states that "some 14,000 lakes in eastern Canada have pH levels of less than 5" and that "some 150,000 lakes in eastern Canada have pH levels of less than 6." (McMillan, 1988, pp. 3, 4). Further, it notes that Canadian lake data provided to NAPAP were not used. The absence of Canadian lake data in the Interim Assessment was also noted by other critics, including the NRDC and Congressman Scheuer.

Analysis:

The Canadian critique is correct in observing that Canadian modeling and survey data were provided to NAPAP and that their interpretation had been agreed to previously (RMOC and NAPAP, 1987). NAPAP recognizes that acidic deposition has contributed to the acidity of some Canadian lakes. NAPAP will evaluate Canadian surface water data in the 1990 Integrated Assessment.

NAPAP scientists are aware of the surface water acidity in Canada. The Interim Assessment reflected a primary reliance on data from surveys specifically designed to allow population inferences to be drawn with known confidence.

The Canadian critique asserts that specific numbers of lakes have pH less than 5.0 (14,000 lakes) or less than 6 (150,000). These numbers are consistent with published estimates (Kelso et al., 1986; Jefferies et al., 1986). These estimates come from distillations of multiple surveys conducted over a period of years. Thus, the uncertainty of the estimates is undefined, but larger than those for the National Surface Water Survey (NSWS). The Canadian lake estimates (when expressed as a percentage of the total population of lakes) are generally similar to results from northeastern regions of the U.S. Eastern Lake Survey. The percentage of lakes with pH less than 5.0 ranges from 1 to 10 percent in subregions of both the eastern United States and eastern Canada, with an average of about 2 per cent in eastern Canada. (However, Nova Scotia and Florida are estimated to have a significantly higher percentage of lakes with pH less than 5.0. In both of these regions important subpopulations of lakes are acidic as a result of natural organic acids rather than from acidic deposition.) The percentages of lakes with pH less than 6.0 in the two nations are also similar, ranging from 4 to 44 percent in Canadian regions (again except for Nova Scotia which had 82 percent of its lakes with a pH less than 6.0) and from 5 to 33 percent in northeastern U.S. regions.

Uncertainty:

The Canadian data were collected without regard to an underlying statistical design or framework, consequently the extrapolation of the sample results to the target population is uncertain. The number of sampled lakes is large, which might tend to reduce statistical problems of extrapolation. Large numbers, however, do not necessarily remove bias in the data. This bias might result from a non-random selection process, i.e. selecting only lakes suspected of being susceptible to acidic deposition. This data will receive greater attention and analysis in the 1990 NAPAP Integrated Assessment.

Future Consideration by NAPAP:

NAPAP's plans for future evaluations of the extent of acidic surface waters will:

- 1) provide an explicit definition of the chemical status being defined as well as the limitations inherent in any statement of current chemical status.
- 2) provide a full exposition of National Surface Water Survey results, including their limitations as a result of water body size, sampling methodology, seasonality and other important factors. This exposition will result in a report on the status of lakes and streams in sensitive regions of the country with a high degree of certainty.
- 3) discuss survey results obtained from state programs, Canadian studies, and other North American sources. The strengths and limitations of the data will be stated explicitly including their certainty.

NAPAP's ability to address damage to aquatic resources, rather than their status, is discussed in Section 2.

2. AQUATIC STEADY STATE

Comments:

The Canadian critique suggests that numerous data are available to contradict the Interim Assessment's conclusion of steady state in northeastern surface waters. Other critics concur with the Canadian critique. For example, Dr. Likens (1987) states, "The speculation that 'most watersheds are at or near steady state with respect to sulfur deposition' is inaccurate and misleading." Studies of sensitive lakes in eastern North America, it is claimed, have indicated "continuing deterioration of lake water chemistry and damage to aquatic biota...despite a reduction of acidic deposition" (RMCC, 1987, p.2).

The authors of the Canadian critique further assert that "even if there were chemical equilibrium, biological lags could prolong biological equilibria for years to decades" (RMCC, 1987, p. 25). Several other critics concur with this point. For example, Congressman Scheuer asked, "Isn't it true that even if

the lakes have reached, as a hypothesis, a steady state, a chemical steady state, that at the same time, further biological damage could be occurring?" (U.S. Congress, 1988, p. 58). Schindler (1987) noted that "biological steady state would probably lag [chemical steady state] for one to three decades."

Analysis:

The Executive Summary is careful to refer to "sulfur steady state" or "steady state with respect to sulfur deposition" rather than to a general steady state. The use and definition of "sulfur steady state" in the Interim Assessment is based on observations of the amount of sulfur entering and leaving watersheds. Other notions of steady state, which were not used, could include ANC or base cation steady state. Given NAPAP's definition, the existing data accurately support our statements. Analyses by Rochelle and Church (1987), based on a statistically representative probability sample, provide a firm basis for arguing that, on average, for the distribution of systems in the Northeast, watersheds are "at or near" sulfur steady state as stated in the Interim Assessment. When these same analyses are applied to the Southern Blue Ridge Province, there is no question that, at similar sulfur deposition levels, the Southern Blue Ridge Province is further away from a sulfur steady state than is the Northeast, as stated in the Interim Assessment.

Another result suggesting general population-level sulfur steady state in the Northeast and Upper Midwest, but not in the Southern Blue Ridge Province, can be seen by plotting subregional sulfate deposition against subregional surface water sulfate concentrations. In these plots, the points fall out along a line except for the point for the Southern Blue Ridge Province. For this subregion, the surface water sulfate concentration is lower than would be expected given the estimated wet sulfate deposition. This result suggests that sulfur is generally being retained within the watersheds of the Southern Blue Ridge Province and that these systems may change in the future under continued levels of deposition as stated in the Interim Assessment. It also suggests that if sulfur deposition changes in the Northeast, then so will sulfur in those surface waters.

The extent to which the continued deposition of sulfur can lead to additional acidification (i.e., a decrease in ANC) over a long period of time even after a "sulfur steady state" has been reached, due to the depletion of base cations, is a subject of debate. The work of Dillon et al. (1987) on two lakes in Canada certainly suggests that continued acidification after reaching sulfur steady state is possible. However, changes in nitrate flux through terrestrial systems as well as changes in base cation deposition need to be explored as possible factors responsible for the changes observed by Dillon.

Analysis of NSWS data indicates a positive relationship between sulfate and base cation concentrations in lakes, which suggests that on a regional basis lake base cations increase with sulfate deposition, so that in most instances, ANC and pH are not much affected. Changes in chemistry which may occur after reaching sulfur steady state could lead to additional changes in the distribution or abundance of organisms. However, the time lag between chemical change and biological change is not well characterized, although NAPAP agrees with the reviewers that, at least for fish, the time scale may be years to decades.

NAPAP is addressing the potential for acidification to occur after sulfur steady state is reached. However, using preliminary data the results of watershed models suggest that acidification of northeastern surface waters would be much slower and less extensive after reaching sulfur steady state than would occur while the system is reaching sulfur steady state.

In contrast to the northeast, southeastern and mid-Appalachian surface waters do not appear to be at steady state with respect to sulfur deposition. These waters may be vulnerable to a loss of ANC and an increase in sulfate concentration as described in the Interim Assessment. NAPAP's Direct/Delayed Response Project will present more definitive results including estimated response times. These results, based on the application of dynamic surface water acidification models, will be included in the 1990 Assessment.

Evidence for the historical acidification of surface waters is summarized in Section 8.4 of the Interim Assessment (pp. 8-41 ff.) and is highlighted in Tables 8-10 and 8-11 (pp. 8-43 to 8-45). These studies do not indicate that all the acidic surface waters studied have become acidic in the past fifty years. In addition, the studies were not conducted on a statistically representative set of surface waters. Data from an EPRI study⁵ of historical pH reconstructions developed on the basis of diatom remains in lake sediments show recent acidification in some lakes (especially in the Adirondacks), but not in others (especially in northern New England, northern Florida, and the Upper Midwest). The data also show that some lakes were acidic in prehistoric times. These data need to be examined carefully, especially for their regional representativeness.

In summary, the available evidence indicates that the population of lakes in the northeastern United States is at or near steady state with regard to sulfur, i.e., sulfur input equals sulfur output.

Uncertainty:

The sulfur input-output analyses make a number of assumptions. Perhaps the most critical of these concerns estimates of dry deposition in calculating the watershed budgets. Dry deposition estimates are highly uncertain; adequate procedures for routinely measuring dry deposition do not exist. If dry deposition estimates are too low, the distribution of systems will be shifted away from sulfur steady-state and indicate sulfur is still being retained by many Northeast systems. Alternatively, if dry deposition estimates are too high, the converse result would be obtained. The controversy over dry deposition estimates is unlikely to be resolved by 1990.

Future Consideration by NAPAP:

The 1990 Assessment will address the issue of steady state using regionally representative data analyzed in the Direct/Delayed Response Project

⁵ PIRLA, Paleolimnologic Investigations of Recent Lake Acidification

(DDRP). Three watershed response models will be employed. These models will predict the status of surface water chemistry in the year 2035, assuming constant deposition at current levels as well as varying deposition levels under a wide array of alternative scenarios. The changes in water chemistry from factors other than acidic deposition will also be considered. The 1990 Assessment will also address the steady state issue in its analysis of fossil diatom data.

Comparative projections of surface water chemistry in conjunction with acidic deposition fifty years into the future are obviously uncertain. These projections, therefore, should not be viewed as absolute, but rather as a means of comparing among the potential effects of alternative deposition scenarios. Because there is uncertainty in the deposition inputs to these watershed models, uncertainty in the processes coded in the models and uncertainty in the parameters used in model calibration, it is important that this error or uncertainty be considered in the resultant output. This permits policy officials to see the relative confidence one can have in comparing among the potential effects of alternative deposition scenarios. The DDRP design provides for such information.

In addition, the operation of the models requires the use of an array of simplifying assumptions, such as constant patterns of land use and nitrogen deposition. These assumptions influence the uncertainty of the model output. The additional level of uncertainty arising from the use of these assumptions will be discussed in the 1990 Assessment.

The 1990 Assessment will define and describe multiple interpretations of chemical steady state, including sulfur input and output as well as more complete chemical steady state. The analyses of chemical change resulting from the use of the DDRP models, combined with our understanding of the response of fish species to chemical change, will allow for estimates of biological change (at least as measured by the presence or absence of some fish species). Other responses of fish to chemical changes will be discussed qualitatively. The certainty of these statements is expected to range from low to moderate depending on the region. Because biological predictions are based on chemical predictions, the certainty of the chemical predictions will be greater than the biological predictions.

The key assumptions, data bases, and linkages involved in making these estimates are outlined in NAPAP's 1990 Assessment Plan to be issued in October 1988.

3. AQUATIC EPISODES: MAGNITUDE AND EXTENT

Comments:

The Executive Summary is faulted for its failure to consider the implications of pH depressions induced by spring runoff and snowmelt. It was asserted that "this phenomenon constitutes a serious risk to aquatic biology" (RMCC, 1987, p. 5). This process is asserted to be "of particular importance in New England and the Minnesota-Wisconsin-Michigan area" (RMCC, 1987, p. 17).

Several critics were concerned about the fall sampling period of the

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NAPAP NSW; arguing that more acidic surface waters would have been enumerated if sampling had been conducted during the spring. Congressman Scheuer stated, "the pH factor is generally higher in the fall than it is in the spring." (U.S. Congress, 1988, p. 55)

Analysis:

The observation that the chemistry of the snowpack can be of critical importance relative to the chemistry of spring runoff and episodic acidification of surface waters is noted in Section 8.3.4 of the Interim Assessment. It is also the first area listed under recommendations for further research under Sections 8.9 and 5.7. In addition, we note the potential for acidic episodes that may be caused by intense summer storms.

Fall turnover sampling was selected for phase I of the National Lake Survey because it provided the most consistent and feasible opportunity for sampling the large number of lakes required to make statistically based population estimates. In addition, fall turnover chemistry is thought to reflect mean annual chemistry. As a result, descriptions of lake chemistry on a population basis reflect the fall sampling. Samples collected at other times of the year might have identified a greater number of acidic lakes, but they would have been a poorer index with which to characterize the current status of lake populations.

Detailed investigations in one Wisconsin lake have shown that seasonal pH depressions are caused largely by increases in carbon dioxide concentrations under the ice. Furthermore, despite an acidic snowpack, the pH depression in the lake could not be attributed to input of acidic meltwater because total alkalinity did not change.

The NAPAP NSW was conducted to answer three general questions:

- . What is the percentage and location of surface waters that are acidic in regions of the U.S. potentially susceptible to acidic deposition?
- . What is the percentage and location of low ANC surface waters in these regions?
- . What are the physical and chemical characteristics of these systems?

A survey was determined to be an effective approach to answering these three questions. The Survey provided a snapshot of the current status and extent of low-pH and low-ANC surface waters in regions of the U.S. potentially susceptible to acidic deposition. It was the characteristics of the population of lakes and streams that was of interest, not individual lakes or streams, per se. The objective was not to determine the absolute minimum pH or ANC value for each system because this value will be highly variable and requires a continuous sampling effort to measure it. The objective was to collect a water sample that would be used as an index to the status of that water body and be compared to indices from other water bodies to describe the population status of surface

waters.

It was determined that about 1600 lakes in the eastern U.S. and about 1000 lakes in the western U.S. needed to be sampled to characterize statistically the population of lakes. This sampling had to occur during a comparable period in all lakes. Extensive analyses indicated the fall period provided the best window of comparability. The lakes would be relatively well-mixed during this period so a single sample could be collected from each lake; the lakes were accessible during this period; the lakes would reflect a chronic acidic or low ANC status during this period; and this period would provide a good index for comparing the characteristics among lakes. The fall sampling period, therefore, was the most suitable period to conduct the survey to answer the original three questions.

Uncertainty:

In situ and laboratory bioassay studies, and laboratory experiments indicate that acidic episodes can kill fish. The death of individual fish, however, does not mean that the fish population as a whole is impacted by acidic chemical pulses. In some cases fish can move within the lake or stream and potentially avoid the deleterious effects of acidic episodes. Fish populations also might compensate for mortality through increased growth or fecundity. The impact of acidic episodes on fish populations and populations of other aquatic biota is unknown. Although studies are planned to begin addressing this question, definitive results will not be available by 1990.

Preliminary analyses indicate the percentage of low-pH and low-ANC lakes would be greater during the spring than during the fall period. EPA's analysis of long-term monitoring data on lakes in the Northeast and Upper Midwest indicated that spring ANC values were generally lower but spring pH values were either comparable or only slightly lower (Newell et al, 1987). These differences, however, varied considerably from year to year. In some years, pH and ANC were comparable in the fall and spring, while in other years, the spring and fall values were different. The difference between spring and fall will reflect the annual and interannual variability in winter conditions (i.e. amount of snowfall, winter warming periods, time of ice-out, etc.). Analyses are underway to calibrate fall values against limited spring data to determine if there is a general relation, albeit noisy, between the fall values and the spring values.

Future Consideration by NAPAP:

The Aquatic Effects Research Program initiated an Episodic Response Project (ERP) in 1987. During the winter of 1988/89, the ERP will sample the snowpack and stream water chemistry in several clusters of watersheds in the Appalachian plateau of western Pennsylvania as well as in the Catskill and Adirondack Mountains of New York. NAPAP plans to include the results and interpretation of these studies in the 1990 Assessment. Information on episodes from other major programs, such as the Maryland Power Plant Research Program's work on anadromous fish in Chesapeake Bay tributaries will also be evaluated.

Major New Findings in Aquatic Effects

Comment:

Congressman Scheuer requested the review of several recent papers on aquatic effects of acidic deposition including: Schindler, 1988; Dillon et al, 1987, the work of Dr. Galloway in sampling trout streams in Virginia, and the National Stream Survey. An exhaustive review of this literature will be included in the NAPAP State of Science and Technology Reports. This section summarizes Schindler's work as well as Dillon's, but does not include a discussion of Dr. Galloway's work because the study is not yet in the peer-reviewed literature. Nonetheless, we have no reason to question the results reported in his letters or Congressional testimony.

Schindler (1988):

The review article discusses the extent of acid-sensitive areas in the U.S. and Canada and uses the NAPAP NSWS survey results to identify these areas. It defines an alkalinity of 50 $\mu\text{eq/l}$ as indicating an extremely acid sensitive water and notes that such waters are widespread in eastern North America. Rates of increase of acidic deposition and the extent and rate of surface water acidification are difficult to estimate because reliable long-term records are not available. However, using geochemical theory, analysis of long-term trends, comparisons of older with more recent chemical records and paleoecological analyses, the estimated rate of acidification of surface waters has increased less rapidly than was feared a decade ago. These four lines of evidence do indicate that lake and stream acidification has occurred in geologically sensitive North American areas receiving precipitation containing strong acids. Buffers to surface water acidification exist not only in the watershed, but also as a result of processes that occur in the water bodies themselves. Schindler also states that "Changes in the chemistry of precipitation have occurred so frequently that steady state between atmospheric inputs and lake chemistry cannot have been reached for lakes with long water-residence times."

Evaluating the biological change associated with surface water acidification requires a consideration of other life stages besides adult fish and organisms in addition to fish. In many instances, the minimum pH values tolerated by these life stages or organisms are higher than for adult fish. Episodes of low pH are biologically important. The importance of aluminum appears to vary with the organism and ecosystem in question, and with the pH level.

Decreases in sulfate deposition in Sudbury and decreased U.S. and Canadian SO_2 emissions have resulted in the chemical recovery of some fresh-water systems. While chemical recovery of surface waters following decreased sulfate deposition might be fairly rapid, unassisted biological recovery will occur more slowly and might require years to decades for partial recovery.

The article concludes by recommending a limit to sulfate deposition of "somewhere 9 to 14 kg/ha/yr to protect our most sensitive aquatic ecosystem".

Analysis:

Qualitatively and mechanistically, there is little disagreement between NAPAP and Dr. Schindler's review. The differences lie in quantifying the extent to which the evidence supports Dr. Schindler's view of the extent of the aquatic effects of acidic deposition. Further, NAPAP would not recommend a specific level of wet sulfate deposition as a target loading. The uncertainties implicit in stating a target loading are too great at this time. The Direct Delayed Response Project will make predictions about the future of surface water acidity under various deposition scenarios, with more thoroughness and certainty than has previously been possible. The results are likely to show that various regions and subpopulations of surface waters within the regions have differential responses to changes in deposition.

Dillon et al. (1987)

This study reported on the "first direct observations of the acidification rate of a lake that has undergone extensive damage to its aquatic biota as a result of deposition of acids of anthropogenic origin. A threefold decrease in alkalinity and a decrease of 0.2 pH units occurred in the lake despite a reduction in the deposition rate of strong acids over the period of study. Acidification was accompanied by a decrease in base cation content in the lake but not an increase in strong acid anion (sulfate) concentration, indicating that there has probably been a depletion of base cations in the lake's catchment."

Analysis:

Change in lake pH and alkalinity after reaching sulfur steady state is discussed in the section on steady state. There are three dominant issues raised by this study. The first is the relative magnitude of chemical change associated with base cation depletion as compared to the magnitude of chemical change associated with the development of a sulfur steady state. The second is the unknown representativeness of the results obtained at Plastic Lake as compared to other lakes, and the third is potential changes in nitrate flux through, or base cation deposition to the watershed. All of these issues need to be considered in evaluating this paper.

National Stream Survey:

The National Stream Survey (NSS) field activities were conducted in four mid-Atlantic subregions and five Southeast subregions in the spring of 1986 as part of the NSWS (See regions sampled in Figure 1 of this analysis). These subregions of the United States were expected, on the basis of geology, deposition rates, and previous water quality data, to have the highest probability of containing streams with low acid neutralizing capacity (ANC) or low pH. Furthermore, NSS efforts during 1986 were concentrated in areas where acidic deposition rates are relatively high, but where lakes are not abundant. The NSS also was designed within a statistical frame that permitted extrapolating

FIGURE 1

SUBREGIONS OF THE NATIONAL STREAM SURVEY - PHASE I

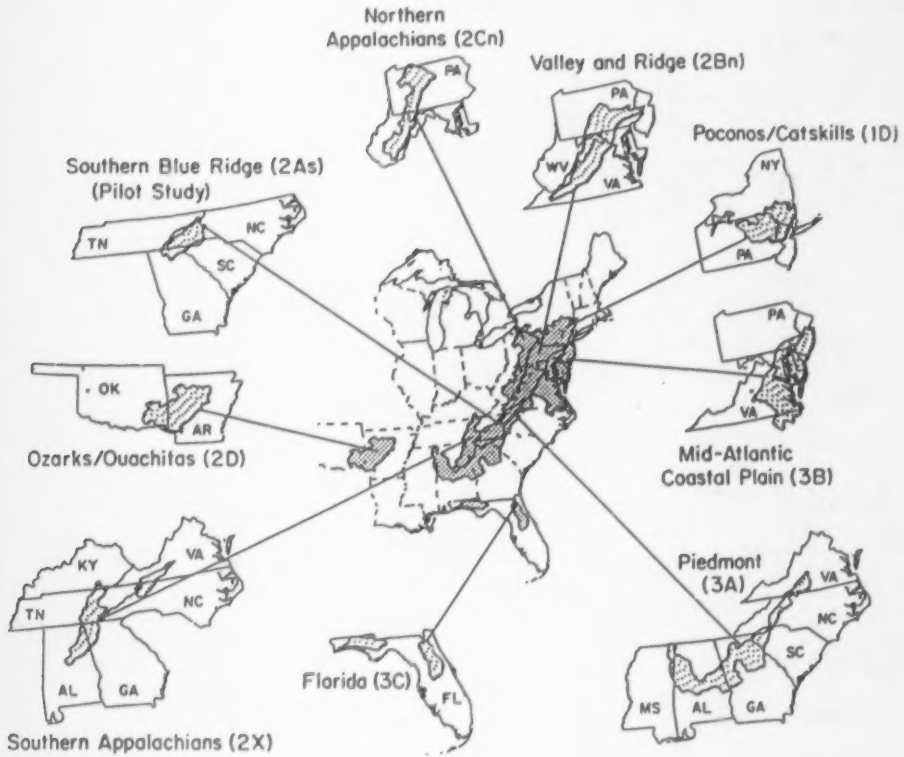


TABLE 3A
NATIONAL STREAM SURVEY RESULTS FOR ANC

Population Estimates of the Combined Length (km) and Percentage of NSS-I
Target Stream Reaches with Spring Baseflow ANC Less than Reference Values
(Standard Errors in Parentheses).[#]

Subregion	ANC ≤ 0		ANC ≤ 50		ANC ≤ 200		Total Length (km)
	Length	%	Length	%	Length	%	
Poconos/Catskills	543 (270)	3.6 (1.8)	1,606 (500)	10.6 (3.3)	5,489 (1,100)	36.2 (7.3)	15,144 (1,912)
N. Appalachians	1,524 (750)	7.0 (3.5)	3,713 (920)	17.1 (4.2)	12,935 (2,200)	59.5 (10)	21,738 (2,746)
Valley & Ridge	257 (210)	0.8 (0.6)	2,111 (990)	6.5 (3.0)	12,811 (3,400)	39.2 (10)	32,687 (4,492)
MA Coastal Plain	2,527 (1,200)	6.3 (2.9)	9,636 (2,700)	23.9 (6.6)	21,091 (4,400)	52.3 (11)	40,296 (5,799)
S. Blue Ridge	*	*	706 (250)	7.8 (2.8)	7,084 (940)	78.4 (10)	9,036 (960)
Piedmont	*	*	2,390 (1,300)	7.1 (3.9)	13,554 (2,900)	40.4 (8.5)	33,531 (4,402)
S. Appalachians	117 (120)	(0.5) (0.5)	763 (440)	3.5 (2.0)	6,130 (1,700)	28.0 (8.0)	21,892 (2,807)
Ozarks/Ouachitas	*	*	205 (150)	0.9 (0.6)	15,092 (2,500)	67.1 (11)	22,480 (2,507)
Florida	461 (160)	12.0 (4.1)	2,356 (530)	61.2 (14)	2,939 (590)	76.4 (15)	3,848 (678)
SUBTOTALS							
Interior MA	2,324 (1,000)	3.3 (1.4)	7,431 (1,700)	10.7 (2.4)	31,235 (4,300)	44.9 (6.2)	69,569 (5,601)
Interior SE	117 (120)	0.1 (0.1)	4,064 (1,300)	4.7 (1.5)	41,860 (4,300)	48.1 (4.9)	86,939 (5,871)
Mid-Atlantic (MA)	4,851 (1,600)	4.4 (1.4)	17,067 (3,100)	15.5 (2.8)	52,327 (6,200)	47.6 (5.6)	109,865 (8,063)
Southeast (SE)	578 (210)	0.6 (0.2)	6,420 (1,500)	7.1 (1.7)	44,799 (4,400)	49.3 (4.8)	90,787 (5,910)
Total NSS-I	5,429 (1,500)	2.7 (0.8)	23,487 (3,400)	11.7 (1.7)	97,125 (7,700)	48.4 (3.8)	200,652 (9,996)

[#] Calculated using linear interpolation between upper and lower reach nodes. Standard errors were approximated by an ad hoc procedure using the variances of separate length estimates based on the upstream and downstream nodes.

* No samples observed below this reference value; estimated percentage is less than 1%.

NOTE: To calculate upper and lower one-sided 95% confidence bounds, multiply the standard error by 1.645 and add or subtract that value from the length estimate. To calculate the two-sided 95% confidence bounds, multiply the standard error by 1.96.

TABLE 3B
NATIONAL STREAM SURVEY RESULTS FOR pH

Population Estimates of the Combined Length (km) and Percentage of NSS-I Target Stream Reaches with Spring Baseflow pH Less than Reference Values (Standard Errors in Parentheses).*

Subregion	pH ≤ 5.0		pH ≤ 5.5		pH ≤ 6.0		Total Length (km)
	Length	%	Length	%	Length	%	
Poconos/Catskills	550 (290)	3.6 (1.9)	906 (420)	6.0 (2.8)	1,354 (520)	8.9 (3.4)	15,144 (1,912)
N. Appalachians	1,424 (700)	6.6 (3.2)	1,870 (710)	8.6 (3.2)	3,044 (900)	14.0 (4.2)	21,738 (2,746)
Valley & Ridge	257 (260)	0.79 (0.8)	1,937 (1,300)	5.9 (4.0)	4,116 (1,900)	12.6 (5.9)	32,687 (4,492)
MA Coastal Plain	3,147 (1,300)	7.8 (3.3)	9,565 (3,000)	23.7 (7.5)	18,707 (4,300)	46.4 (11)	40,296 (5,799)
S. Blue Ridge	•	•	•	•	•	•	9,036 (960)
Piedmont	•	•	•	•	2,390 (1,200)	7.1 (3.7)	33,531 (4,402)
S. Appalachians	•	•	313 (310)	1.4 (1.4)	920 (540)	4.2 (2.5)	21,892 (2,807)
Ozarks/Ouachitas	•	•	410 (290)	1.8 (1.3)	2,437 (990)	10.8 (4.4)	22,480 (2,507)
Florida	522 (250)	13.6 (6.5)	1,708 (440)	44.4 (12)	2,828 (620)	73.5 (16)	3,848 (678)

SUBTOTALS							
Interior MA	2,231 (780)	3.2 (1.1)	4,712 (1,700)	6.8 (2.4)	8,514 (2,300)	12.2 (3.4)	69,569 (5,601)
Interior SE	•	•	723 (430)	0.83 (0.5)	5,747 (1,700)	6.6 (1.9)	86,939 (5,871)
Mid-Atlantic (MA)	5,378 (1,500)	4.9 (1.4)	14,277 (3,400)	13.0 (3.1)	27,221 (4,800)	24.8 (4.4)	109,865 (8,063)
Southeast (SE)	522 (250)	0.57 (0.3)	2,431 (800)	2.7 (0.9)	8,576 (1,900)	9.5 (2.1)	90,787 (5,910)

Total NSS-I	5,900 (1,600)	2.9 (0.8)	16,708 (3,400)	8.3 (1.7)	35,797 (5,200)	17.8 (2.6)	200,652 (9,996)

* Calculated using linear interpolation of $[H^+]$ between upper and lower reach nodes. Standard errors were approximated by an ad hoc procedure using the variances of separate length estimates based on the upstream and downstream nodes.

• No samples observed below this reference value; estimated percentage is less than 1%.

NOTE: To calculate upper and lower one-sided 95% confidence bounds, multiply the standard error by 1.645 and add or subtract that value from the length estimate. To calculate the two-sided 95% confidence bounds, multiply the standard error by 1.96.

from the sampled stream reaches to the population of stream reaches within a subregion or in a region. The index period for the NSS was spring baseflow. Results, including estimates of statistical uncertainty, are summarized in Tables 3A and 3B.

The NSS allows the physical and chemical characteristics of an estimated 57,000 stream reaches with a combined length of approximately 200,000 km to be extrapolated from a probability sample of approximately 450 stream reaches in the stream population of interest within the nine NSS-I subregions. The population of streams targeted by the NSS is best described as small to mid-sized streams in the low end of the size range typically managed by state fishery agencies. Stream reaches sampled by the NSS are typically about 3 km long. At their upstream ends, approximately half of these stream reaches are classified as headwater reaches on 1:24,000-scale topographic maps. Median drainage areas at the upstream and downstream end of the population of target stream reaches are 1.5 km² and 8.1 km². Twenty percent of these reaches have drainage areas less than 0.18 km² at their upstream ends. The majority of these streams have widths between 1 and 6 m and depths between 0.1 and 0.5 m.

For the entire NSS target population, 2.7 percent (5,429 km) of the combined length of streams were acidic (i.e., ANC < 0). This percentage varied by region with about 4 percent of the combined length of streams acidic in the mid-Atlantic target population and about 1 percent of the combined length of streams acidic in the Southeast target population. The greatest percentage (12 percent) of acidic combined length of streams occurred in the Florida subregion. The Northern Appalachians and Mid-Atlantic Coastal Plain subregions both had about 7 percent of their reaches acidic, which were the subregions outside of Florida with the greatest percentage of combined length of acidic streams. No acidic streams were observed in the Southern Blue Ridge Province or in the Piedmont.

About 12 percent of the combined length of streams in the NSS target population had ANC < 50 ueq/l, a value commonly used to indicate waters which are very sensitive to acidic deposition⁶. About 16 percent of the estimated stream length in the Mid-Atlantic Region and about 7 percent of the estimated stream length in the Southeast Region had ANC < 50 ueq/l. Within the nine NSS subregions, the percentage of stream length with ANC < 50 ranged from 1 percent in the Ouachitas of Arkansas to over 61 percent in Florida. About 48 percent of the combined length of streams in the NSS target population had ANC < 200 ueq/l. Waters with an ANC above 200 are generally agreed not to be sensitive to acidification. Patterns in stream pH generally followed the distribution of ANC. An estimated 3 percent of the combined stream length in the NSS had pH < 5.0, 8 percent had pH < 5.5, and 18 percent had pH < 6.0. Regional variation in stream water ANC was closely associated with concentrations of base cations (e.g., sodium, potassium, magnesium, and calcium), indicating that local geology is probably the primary factor controlling the chemistry of streams.

⁶Low ANC is only one condition necessary for surface waters to be regarded as sensitive to acidification. Associated watershed characteristics such as sulfate retention, base cation exchange capacity, and hydrology must also be considered when characterizing the sensitivity of surface waters.

Of the estimated 3 percent acidic NSS target stream reaches, over half of these high-interest reaches drained small ($> 20 \text{ km}^2$) upland forested watersheds in the interior Mid-Atlantic, whereas most of the remainder occurred in lowland drainages of the Mid-Atlantic Coastal Plain subregion, primarily in the New Jersey Pine Barrens. However, most of the streams in the Pine Barrens are also influenced by organic acidity, and many are likely to have been acidic at least since the early 1900's.

Subregional median stream water sulfate concentrations (excluding streams with substantial internal watershed sulfate sources) were highly correlated with subregional median wet sulfate deposition rates. This finding supports the hypothesis that atmospheric inputs of sulfate are the major source of sulfate in these streams. This correlation was also observed in lake populations in the National Lake Survey.

Organic acidity, which characteristically results from the natural decay of vegetation, is likely to be the major source of acidity in the majority of streams in the Florida subregion. Similarly, natural organic acids were estimated to be the major source of acidity in about half of the streams in the Mid-Atlantic Coastal Plain subregion.

Acid mine drainage impacts are common in some NSS subregions. In the Northern Appalachians subregion, acid mine drainage affected roughly 10 percent of the stream population initially sampled in the NSS. Many of the streams affected by acid mine drainage were found in Pennsylvania, West Virginia, and Tennessee.

OTHER EFFECTS

4. FORESTS AND CROPS

4.1 Structure of the Forestry Research Program

Comments:

Some of the criticism of the chapter on Effects on Forests focuses on the description of the research program and its ability to resolve issues raised in the chapter. "The major criticisms of the report itself relate more to the content of the program than the results of specific studies." (RMCC, 1987, p.21). "In the discussion of multiple stresses it is correctly noted that the issue is complex. The discussion, however, neglects to indicate that the issue cannot be resolved using the approach presented in the earlier section entitled 'Forest Response Research'." (RMCC, 1987, p. 22).

Analysis:

The description of the Forest Response Research Program in the Interim Assessment is brief, and does not fully describe the international effort to

understand the effects of multiple stresses on forests. The U.S. program is well coordinated with Canadian government and other research programs. The ongoing U.S.-Canadian coordination activities should help to clarify the elements of the Forest Response Research Program.

4.2 Consolidating Multiple Stresses to Forests

Comments:

Canadian reviewers suggest that:

"...damages to terrestrial systems have been downplayed in the Executive Summary by inappropriately separating acidity impacts to terrestrial systems from the rest of the long-range transport of air pollution effects. Some of these stresses are treated singly in the Summary. A large portion of the multiple air pollution stress impacting on terrestrial systems results directly from emissions of SO_x and NO_x . These emissions lead to acid mists and fogs, ozone production, the depletion of base cations in soils, and the release of toxic and phosphorous-immobilizing aluminum. This critical linkage, and the associated concern with widespread terrestrial effects, is not reflected in the report." (RMCC, 1987, p. 2).

Dr. Schindler (1987) concurs with this view.

The Canadian critique also suggests that, since two of eight cases of apparent forest decline are known to have been caused by air pollution, and since air pollution could not be ruled out in the other six, then there is good reason for action on pollution controls.

4.2.1 General

Analysis:

The Executive Summary attempts to clarify the effects of air pollution, including acidic deposition, on forests by organizing the discussion into major groups of possible mechanisms by which air pollution might affect forest growth. This categorical listing identifies the same potential damage mechanisms as listed in the Canadian critique. In addition, the Executive Summary (p. I-27) notes that multiple stresses might be responsible for the decline. Other portions of the Executive Summary (e.g., Section I.1.3 and particularly Fig. I-2) emphasize the linkages among the pollutants and their precursors.

The specific emphasis on acidic precipitation is appropriate for the mission of NAPAP. Given the state of knowledge with respect to the effects of multiple stresses, as reflected in the peer-reviewed literature, the Executive Summary and Sections 7.4 and 7.5 appropriately address that issue. In fact,

NAPAP-sponsored research commonly employs mixtures of pollutants in laboratories and studies forests that are subject to multiple stresses. It is true that NAPAP focuses on the effects of pollutants, and this is appropriate. Effects of other stresses are not ignored, however. Ongoing research in the Forest Response Program will improve our understanding of these more subtle, complex, and long-term effects, including those arising from multiple stresses. However, NAPAP will not produce a final answer to the issues of multiple interacting stresses on forests for the 1990 Assessment.

4.2.2 Ozone

Analysis:

The two known cases of U.S. forest decline attributable to ozone have occurred in ponderosa and Jeffrey pines in the San Bernardino and Sierra Nevada Mountains in California and in sensitive genotypes of white pine in the eastern United States (NAPAP, 1987, p. 7-17). The other six cases of forest decline mentioned in the Interim Assessment might be attributable to air pollution and/or natural causes. If they are attributable to air pollution, the cause may be oxidants, acid rain, some other factor or combination of factors. Discrimination between these agents allows control strategies to be evaluated. However, recommendations either to pursue or not to pursue control strategies were beyond the scope of the Interim Assessment.

4.3 Existence of Effects

4.3.1 Foliar-mediated effects of acidic precipitation on plants

Comment:

Dr. Likens suggests that there are direct effects on foliage of plants in rain and cloud water at ambient pH levels in the eastern United States. He lists five references to support this view.

Analysis:

The conclusion that short-term, direct effects on tree foliage is unlikely is a reasonable one, based on the information in the current scientific literature. However, several NAPAP-funded studies underway will provide additional evidence to confirm or deny this conclusion in the next 1 to 3 years. Two of Dr. Likens' citations refer to tree species. One refers to cation leaching from ambient rain using throughfall collection, deposition monitoring and a series of assumptions to estimate ion exchange. The report does not indicate that the trees were damaged from cation leaching. The second research paper reports on an experiment using higher than ambient levels of acidity. The other three references cited by Dr. Likens are review articles rather than primary research reports. NAPAP's review of the primary crop literature suggests that as more and more experiments are conducted the certainty becomes greater and greater that there are no effects on crops from acidic rain.

4.3.2 Effects of acidic precipitation on crops

Comment:

Dr. Likens suggests that the "logic and order of presentation in paragraphs I.3.7.1 and I.3.7.2 defy imagination." (These sections of the Executive Summary are entitled "Impact of Ambient Acidic Rain on Crop Production" and "Effects of Highly Acidic Rain or Fog", respectively.)

Analysis:

The first paragraph under I.3.7.2 states that no consistent demonstrable effect on the yield of agricultural crops has been observed at ambient levels. To further reduce any small remaining uncertainty with respect to the lack of regional effects at ambient levels, more studies are being conducted at extreme levels of acidity. These studies may identify effect mechanisms which may then be examined for their possible subtle role at ambient levels.

The final paragraph on p. I-25 describes the work at extreme levels of acidity. It indicates that at high levels of acidity (clearly meaning higher than ambient) a few controlled experiments have suggested possible interactions between rain acidity and other plant stresses. It states that further research on interactions is needed to determine whether such special conditions result in susceptibility to damage within the ambient range of rainfall acidity, since the overwhelming majority of studies have not reported damage to crops from ambient levels of acidity or from interactive effects.

Uncertainty:

The Interim Assessment's conclusions with respect to crops were based on the most reliable field studies completed at that time. These 46 studies of eight crop species represent 74 percent of the value of all crops harvested and are listed in the Interim Assessment (NAPAP, 1987, Table 6-7). Several hundred other experiments have been conducted that have lower levels of confidence than the 46 field experiments, but these studies expand to 34 the number of crop species examined. This broader group of experiments supports the Interim Assessment's basic conclusion on crops.

4.4 Potential Rate of Forest Change

Comment:

Congressman Scheuer (U.S. Congress, 1988, p. 65) questioned the conclusion "that no abrupt changes in forests are likely."

Analysis:

The Executive Summary (NAPAP, 1987, p. I-8) states:

"With the possible exception of above-cloudbase forests where high mortality has occurred from unknown causes, most U.S. forests are not expected to show an abrupt change in health at current ambient air pollutant concentration levels and deposition rates."

Forests (below cloudbase) have been exposed to current levels of air pollution and acidic deposition for a considerable period of time, and no abrupt changes suspected to be related to acidic deposition have been observed. Further, it is unlikely that effects resulting from chronic exposure, such as changes in soil chemistry relevant to forest growth, would affect a large area of forests abruptly. There is too much variability in the buffering mechanisms which protect these forests. These observations and considerations also suggest that the acute mechanisms proposed for forest decline are unlikely to yield abrupt changes, if present dosages remain constant.

This conclusion is derived from observations of current effects, and logical inference and extrapolation of existing hypotheses concerning the role of acidic deposition in forest health. If the actual process involved in changing forest health includes one of these mechanisms, then the conclusion is sound. If the mechanisms involved in affecting forest growth depend on other processes by which acidic deposition or other factors may affect forest health, then the conclusion is more uncertain.

4.5 Unexplained Dieback of Low-Elevation Hardwood Forests, Including Sugar Maple in Quebec

Comments:

Canadian reviewers note that the Executive Summary makes no mention of the recent unexplained dieback of low-elevation hardwood forests in the northeastern United States and southeastern Canada. They point particularly to the extensive dieback of sugar maple in the Province of Quebec. Canadian reviewers note that the sugar maple dieback is located in the region of heaviest deposition and might therefore be a phenomenon in which acidic deposition plays a major role.

Analysis:

The forestry section of the Executive Summary is process-oriented and does not specifically mention any of the unexplained forest diebacks in North America. The synopsis of Chapter 7, which is included in the Executive Summary, mentions specific instances of forest decline in the United States (including low-elevation hardwood forests in the Northeast). Section 7.2, "Case Histories of Regional Tree and Forest Declines", identifies and discusses the regional case histories of forest decline for which air pollution may be considered as a possible causal agent. Subsection 7.2.6 discusses sugar maple decline in the northeastern United States and southeastern Canada. This section notes that soil effects from acidic deposition resulting in sugar maple decline might be occurring, but have not been intensively examined or demonstrated at this point. The section concludes by noting the ongoing cooperative project between NAPAP and the Canadian Forestry Service to elucidate the causes of the decline.

4.6 Extrapolating Seedling Experiments to Forests

Comments:

Canadian reviewers expressed concern that much of the NAPAP work in the area of forest effects is being conducted by means of laboratory and chamber studies on seedlings. It is suggested that such an approach precludes studies at the stand level, and does not adequately address the possibility of indirect, or second-order, effects. There was some concern that the laboratory study approach would de-emphasize other results drawn from field work (RMCC, 1987, p.21). Canadian reviewers also expressed concern as to whether seedling studies can be reliably extrapolated to mature trees and forests.

Analysis:

Analysis of the response of forests to air pollution requires multiple approaches, since no single approach can be relied upon to identify the causes of the described declines. The combinations of approaches used in the Forest Response Program provide a potent and discriminating set of analytical tools. NAPAP believes it has designed a logical progression of work, given the inability to conduct controlled experiments with entire forests in the field. Moreover, NAPAP research must focus upon pollution effects, and studies of direct effects upon individual trees are an appropriate starting point.

NAPAP agrees that research on tree seedlings under controlled conditions does not directly apply to forest decline. Controlled experiments are, however, essential, because field correlation studies alone provide an insufficient basis for establishing cause-effect relationships in the field. In the U.S. program, controlled experiments are conducted in the laboratory and in field chambers, and work is underway with controlled exposures of sapling trees, grafts of mature tissue, and branches on mature trees. Field correlations are also being developed. The detection of stand-level effects, effects on mature trees, or on forests, and indirect or interactive effects are all consistent with the approach described. Air pollution effects in forests must be interpreted with reference to other stresses on those forests, and thus NAPAP is investigating the potential role of a variety of possible decline agents.

4.7 Soil-Mediated Effects

Comments:

There are several comments in the Canadian critique that pertain to the status of forest soils. Canadian reviewers take exception to the fact that NAPAP reported the absence of soil-mediated effects when available data were insufficient to prove such absence. Therefore, it is claimed that statements alluding to the absence of effects were premature and contradict findings in the Interim Assessment and other studies not referenced by the Interim Assessment. The critique also suggests that the report has several internal contradictions, cites controversial literature, and should discuss soil liming and its costs more fully.

The critique notes:

"Ambient acid precipitation will not likely impact agricultural crops. However, there are consequences of acid being deposited on soils, especially those of low acid buffering capacity. The quality of the soils must change unless they are limed." (p. 6).

"The impact on plantation forests is downplayed since the soils can be limed and fertilized. There is no indication of the cost of such undertakings." (p.21).

4.7.1. Soil-Mediated Effects of Acidic Precipitation on Forests

Analysis:

The Interim Assessment, particularly in Sections 7.5, "Indirect Effects/Soil Acidification", and Section 7.2.6, discusses the possibility of acidic deposition effects on forests as mediated through changes in soil chemistry. The literature in this field is far-ranging, reflecting the numerous hypothetical mechanisms by which acidic precipitation may alter forest soils to the detriment of forest productivity. Some of the confusion and difficulty in this area may reflect the fact that changes in forest soil chemistry do not necessarily lead to readily detectable changes in forest productivity. Soil acidification literature was recently evaluated by the Swedish Environment Protection Board (Berden et al., 1987). This review pointed out that a number of factors, including acidic deposition, can decrease soil pH.

This continued debate reinforces the need to conduct the research outlined in Section 7.9.3 of the Interim Assessment. The identification of forest soil types which are potentially sensitive to change by ambient acidic deposition, and the relationship between soil alteration and tree health, are areas in which NAPAP expects to make significant progress by 1990. These studies were discussed in the Executive Summary of the Interim Assessment (p. I-7), and are currently underway. Beginning to understand long-term soil-mediated acidic deposition effects on productivity and forest health for a wide variety of forest soils is one of the 1990 research objectives of the Terrestrial Effects Task Group. In the near term, work under this objective this includes a 1988 report which assesses the impact of sulfate and nitrogen deposition on Southern forest soils.

Thus, in reviewing the information in the Interim Assessment, another recent summary of soil acidification, and the Task Group plans, we agree with the Critique that: 1) there are mechanisms hypothesized by which soil-mediated effects of acidic precipitation could alter forest productivity; and 2) a sound research and data base is lacking to enable predictions about the magnitude of potential soil-mediated effects. NAPAP is in communication with Canadian and other researchers about how to progress on the issue and, as a result, the 1990 Assessment will allow for a more focused discussion of this issue.

4.7.2 Soil Liming

Analysis:

Cost, or expected return on investment, would play a major role in determining whether forests would be limed to minimize potential or actual effects of acidic deposition as mediated through the soils. As the Canadian critique notes, the Interim Assessment does not discuss the economics of forest liming. NAPAP did not analyze the issue as forest liming is unlikely to be practiced over large areas on a routine basis, although it "could be used as a special mitigating measure for extremely unique or high-value forests, as in parks or historical landscapes." (NAPAP, 1987, p. 7-4). To the extent that some plantation forest soils are considered "extremely unique or high-value forests," forest liming may be a potential practice. A more general practice of widespread liming of plantation forest soils is unlikely.

Acidic deposition would lead to changes in unmanaged soils over some period of time. However, for agricultural land the application of nitrogen fertilizers and the growth of leguminous crops acidify soil by an order of magnitude (i.e., a factor of 10) more than that of the contribution from wet deposition (NAPAP, 1987, p. 6-26). Detrimental consequences of increased soil acidity will not occur on managed agricultural soil if typical liming practices are followed to adjust the soil to optimum pH (NAPAP, 1987, p. 6-42). The amount of lime necessary to neutralize the wet deposition of hydrogen ion has been estimated to be about 0.5 percent of the total amount of lime currently applied to agricultural soils (NAPAP, 1987, p. 6-43). Even when the possible increased need for lime is considered, acidic deposition probably benefits agricultural soils because of the fertility benefit from sulfur and nitrogen input (NAPAP, 1987, p. 6-44). For soil of unmanaged grass lands without significant buffering capacity, increased acidity over the long term is conceivable, and possible implications are discussed (NAPAP, 1987, p. 6-26).

4.8 Discrepancies among Descriptions, Figures, and Source Material concerning Effects on Trees

Comment:

Dr. Likens (1987) suggests that the Executive Summary (Section I.3.8.2) is misleading in referring to an adverse effect on foliage in the text while referencing a figure (Fig. I-14) that shows trends in diameter growth of seedlings. He also draws attention to the text in Section I.3.8.4 which discusses exposure of trees in concentration (ppb) while referencing a figure (Fig. I-15) showing dosage (ppm-hr). He also noted that the figure had also been changed in adaptation from the original (by Reich and Amundsen, 1985) and that the text of the Interim Assessment differed from the source text in its statement of the ambient ozone dosage.

Analysis:

Section I.3.8.2 was meant to refer to "foliar-mediated effects", hence the reference to Figure I.14 as an example. In fact, the work cited (Kelly et al, 1984) included analyses of foliar changes such as stomatal density, leaf senescence, cuticle density, and other effects; none of which were found. The ambient range cited in this figure is consistent with the range quoted throughout the Assessment. As the introduction to this section notes (I.3.8), these conclusions are subject to refinement and revision as more experiments and observations are completed. NAPAP is conducting experiments to determine effects on Northeastern tree species. Many more experimental results will become available over the next three years.

Figure I.15 is an inappropriate reference for statements made regarding O_3 concentrations in section I.3.8.4. The statements made in this section are accurate, however. This same figure appears as figure 7-14 in Chapter 7, where it is discussed in more detail. Dr. Likens is correct in pointing out that Reich and Amundsen state that ambient O_3 in the eastern U.S. during a 10-week period in the summer ranges between 0 to 45 ppm hr. For example, a 12-hr average O_3 concentration of 0.05 ppm would produce a dose of 42 ppm hr. (0.05 ppm 12 hr/day x 7 days/week x 10 weeks). This ambient dose range, however, cannot be directly compared to the experimental dosages recorded by Reich and Amundsen because they used a different method for calculation. Their O_3 fumigations occurred for 5.5 or 7 hrs. a day; 3, 5, or 7 days a week, for 3 to 12 weeks, depending on the study (see Table 7-5 in Volume IV). Total hours of O_3 exposure calculated for their experiments with soybeans, poplar, pine, oak and maple ranged from 147 to 441 hrs. and averaged 296 hrs., as opposed to 440 hrs. for the ambient calculation (12 hrs./day x 7 days/week x 10 weeks). Thus a direct comparison is not valid. Therefore, to link the experimental exposures to ambient exposures, ambient concentrations were used in combination with the average experimental dosages. The ambient exposure range in Figure 7-14 was calculated using 296 hrs. total exposure (0.03-0.05 ppm x 296 hrs.). The values reported in figure 7-14 are "net photosynthesis" as stated in the figure caption.

It is possible that the slope of the line for sugar maple may be slightly steeper in Figure 7-14 than in the original figure due to an error in graphics preparation. However, this would not change the interpretations in the text.

Future Consideration by NAPAP:

Scientists within the NAPAP terrestrial effects program will collaborate with their Canadian counterparts in developing information on forest health in North America and in determining effects on crops and forests from atmospheric pollutants. Experimental results on plant response to controlled pollutant exposures will be compared with results from surveys of forest condition and crop production. Dose-response information will be used to estimate changes in forest health and crop production under different levels of acidic deposition and gaseous pollutant concentrations. Intensive studies on forest soils will also be conducted. Survey results from the Canadian "Early Warning System" program will be used, as well as information on sugar maple status and health in eastern North America. Results from studies of spruce condition in Canadian high-elevation sites will be examined along with similar U.S. studies. Exposure-response data from Canadian studies of crop and tree

species will be included in the body of data used to determine cause-effect relationships. The certainty of the reports associated with forests will be low to moderate. There will be a high degree of certainty in the crops report. The major assessment questions relating to forest health and crop production, and the resources and methods to be utilized to answer those questions, will be described in the Assessment Plan.

5. HEALTH EFFECTS OF ACIDIC AEROSOLS

Comments:

According to Canadian reviewers the discussion on ambient acidic aerosol exposures and controlled exposure studies does not fully explore the possible link between exposure and health effects. They suggest there are several research programs in the United States and Canada that should have been mentioned since those programs indicate that there is sufficient concern to warrant further study of this issue. On a more general note, the Canadian reviewers claim that the Interim Assessment fails to review "the bulk" of the health work that has been conducted in the United States.

Analysis:

The Interim Assessment notes (p. 10-1) that the U.S. Environmental Protection Agency is currently developing a comprehensive analysis of the possible direct health effects associated with acidic aerosols on the basis of newly available data, as discussed in a draft Acid Aerosols Issue Paper released in February 1988. In June 1988, a subcommittee of the Clean Air Scientific Advisory Committee (CASAC) of EPA's Science Advisory Board recommended that acidic aerosols be listed as a criteria pollutant. The full committee is expected to meet in October to review this recommendation. NAPAP maintains close liaison with the researchers involved in human health studies of air pollution effects, and will include an up-to-date review and analysis of their work in the 1990 Assessment.

The Interim Assessment discussed the results of 28 controlled human exposure studies using acidic aerosols (Table 10-8 and pp. 10-25 to 10-31). These studies indicated that physiological responses to acidic aerosols appear to occur only at levels above those reported in the few direct measurements of sulfuric acid in ambient air. The Interim Assessment stated "the lack of ambient air quality monitoring for acidic aerosols limits extrapolation from effects observed in controlled studies to possible effects resulting from short- or long-term ambient exposure." (p. 10-70). Ongoing studies should provide important information to update these findings for the 1990 Assessment. Relevant exposure measurements of acidic aerosols are listed as a research need in the Interim Assessment. (p. 10-72).

In addition to ambient aerosol acidity (measured as mg/m^3), the issue of delivered dose to the lung (measured as $\text{mg}/\text{kg}/\text{hr}$) is important. However, the state-of-the-art of dosimetry of hygroscopic particles (i.e., acidic aerosols) is not sufficiently advanced for accurate dose predictions based on exposure concentrations. Also, the relative contributions of concentration and time of exposure are insufficiently known to estimate a dose-rate (e.g.,

mg/kg/hr) that has an accurate health risk interpretation. Therefore, these issues are also listed as research needs in the Interim Assessment.

In the few epidemiological studies in which acidic aerosol concentrations were measured, hydrogen ion concentrations were quite low ($< 20 \mu\text{g m}^{-3}$) and there were no reported correlations between acidity and changes in lung functions (pp. 10-41 to 10-42). Pollutant-specific data were not presented in the preliminary analyses of results of two Canadian studies. The reports available from these studies indicated that minimal, if any, acute health effects could be attributed directly to the air pollutants monitored (p. 10-42). The Interim Assessment discussed results from community comparisons in which particulate matter was measured, including the study on hospital admissions in southern Ontario (pp. 10-42 to 10-45). These studies are continuing and will provide better evidence to compare ambient levels of acidic aerosols to respiratory physiology and illness.

Future Consideration by NAPAP:

NAPAP will continue to track closely research and synthesis activities relating to the potential human health effects of acidic aerosols. These activities are likely to increase in intensity and scope if CASAC recommends that acidic aerosols be listed as a criteria pollutant. This activity will help to ensure the depth and breadth of NAPAP's examination of the literature on this subject, and will help to update NAPAP's interim conclusions.

A statement of specific questions to be addressed, data bases to be examined, and methods to be used to assess human health effects will be provided in the draft plan for the 1990 Integrated Assessment. The 1990 Assessment will address all published Canadian health effects studies, including epidemiological studies.

6. VISIBILITY

Comments:

The Canadian critique suggests that one portion of the chapter on visibility understates the importance of sulfate in visibility degradation. The Interim Assessment states: "annual averages for sulfur emissions and coefficient of haze between 1950 and 1980 for the southeast appear to be positively correlated, however, other sources (such as organic carbon) which contribute to haze could also be correlated with changes in visibility." (p. 10-67).

The Canadian critique also suggests that economic benefits could have been calculated for visibility improvements resulting in fewer requirements for instrument flight rules.

Analysis:

There does not appear to be disagreement between the statements regarding visibility reduction and its correlation with fine particulate sulfate made in the Canadian critique and those made in the Interim Assessment. While the section cited and others in the Interim Assessment note the

potential for multiple pollutants to degrade visibility, the Interim Assessment in several instances states the dominant role of sulfate: "Numerous studies have shown a high correlation between light scattering and sulfate. For example, for measurements made in the Allegheny Mountains, Pennsylvania, sulfate alone accounted for 94 percent of the variability in light scattering." (NAPAP, 1987, p. 10-58.) Also, "the reason for the high correlations among fine particles, sulfate, light scattering, and visibility (or its inverse, i.e., haziness) in rural eastern North America is that sulfate is the dominant chemical component of the fine particles in the air." (NAPAP, 1987, p. 10-59.)

Future Consideration by NAPAP:

NAPAP will assess the influence of fine aerosols on visibility and the implications of changes in visibility in the 1990 Assessment. The Assessment Plan will specify the scope and nature of the analyses to be covered. Moreover, more reliable particulate composition and visibility data will be available for the 1990 Assessment for analysis and to better characterize uncertainties. The Assessment Plan will specify NAPAP's plans for economic analyses on changes in visibility related either to changes in aircraft flight patterns or changes in vistas.

7. EFFECTS ON MATERIALS

Comments:

The primary criticisms in the Canadian critique of the Effects on Materials chapter are directed at the NAPAP materials program, rather than the Interim Assessment report itself. The principal concern stated throughout the review is that too little attention has been paid to studies of effects on real structures. The critique expresses lack of confidence that the materials research program will meet important goals.

Analysis:

The highest priority within the materials program has been given to the study of deposition processes and the development of dose-response functions. However, studies on the effects of acidic precipitation on real structures are also included in the current program. Four current projects supported by the U.S. National Park Service are directed at in-situ cultural resource monitoring: 1) an analysis of the corrosion of a series of bronze statues at various locations in the northeastern United States; 2) a direct analysis of material removed from bronze and marble monuments at Gettysburg National Park; 3) an analysis of the weathering of sandstone ruins at Mesa Verde National Park; and 4) an analysis of variations in weathering due to orientation and sheltering on an early 19th-century marble building at Independence National Historical Park. As the development of damage functions nears completion, greater attention will be directed to studies of real structures. NAPAP plans a full peer review of its materials effects program in January 1989.

Future Consideration by NAPAP:

Assessments of materials damage resulting from acidic deposition and from the precursor gases will be included in the 1990 Assessment. The extent to which the Assessment is able to conduct economic analyses will depend on the successful completion of a number of studies. It is likely that analyses for the construction use of galvanized steel and for the cultural use of carbonate stone will be the most complete.

The upcoming peer review of the materials program will provide a foundation for evaluating the scientific progress of the program and will provide a basis for revising elements of the materials assessment studies. A statement of questions to be addressed in the materials assessment and the data bases and analysis methods to be used, will be provided in the Assessment Plan.

SOURCES, TRANSPORT, TRANSFORMATION, AND DEPOSITION

8. PATTERNS OF HISTORICAL AND PROJECTED EMISSIONS OF SO₂

8.1 Historical Emissions Patterns

Comment:

The Canadian critique suggests that the Executive Summary is misleading in stating that SO₂ emissions have been within plus or minus 35 percent of 1985 values since 1910. It suggests that a more appropriate presentation would have noted that emissions have significantly increased since the turn of the century. (McMillan, 1988, p. 1).

Dr. Likens asserts that there are no published data to provide direct support for the statement on page I-10 that manmade acid rain has been present in the eastern United States since before the turn of the century.

Analysis:

The Executive Summary factually describes (NAPAP, 1987, pp. I-10, I-11 and Figs. I-3 and I-4) how SO₂ emissions have changed, both increasing and decreasing, during the twentieth century. The estimated emissions as shown in the Interim Assessment are reproduced as Figure 2 of this analysis. SO₂ emissions have been within plus or minus 35 percent of the 1985 value since about 1910. NAPAP was not suggesting that the pattern of long-range transport of SO₂ has been constant throughout the century. The Interim Assessment does indicate that SO₂ emissions have increased between 1900 and 1985. NAPAP SO₂ emissions estimates for the United States indicate that the increase between 1900 and 1910 was almost 80 percent, and that the total increase between 1900 and 1985 was about 130 percent (from 9 to 21 million metric tons per year).

The paragraph upon which Dr. Likens has commented, in the section entitled "Historical and Current Emissions", concerning historical patterns of acidic deposition does not rely on either published or unpublished precipitation data. Rather, it is clearly an inference from the patterns of emissions

described in that paragraph. Dr. Likens notes that precipitation may have been acidic in cities before 1930. This supports the statement on page I-10 that the geographic distribution and concentration of acidic deposition has changed due to changes in the characteristics of emissions sources.

Uncertainty:

The uncertainty of current national annual emissions of SO_2 are estimated to be ± 12 percent (NAPAP, 1987, p. 1-7). The historical inventory has larger, but less well-quantified uncertainties than the current inventory:

"Reliable industrial production and fuel quality data for the early part of the century are scarce. Many assumptions and generalizations were made in making those estimates, and the resulting emissions estimates are subject to a very high degree of uncertainty. Comparison of the estimates by Geschwandtner et al. [1985] to those of another research project (Husar, 1986) show fairly large discrepancies.... nevertheless both studies show a general trend of increasing emissions in the early part of the century." (NAPAP, 1987, p. 1-9).

Major New Findings in Emissions

Complete U.S. emissions estimates are available for 1986 and "flash" estimates for 1987 are available (Kohout, 1988). These estimates show small changes throughout the period:

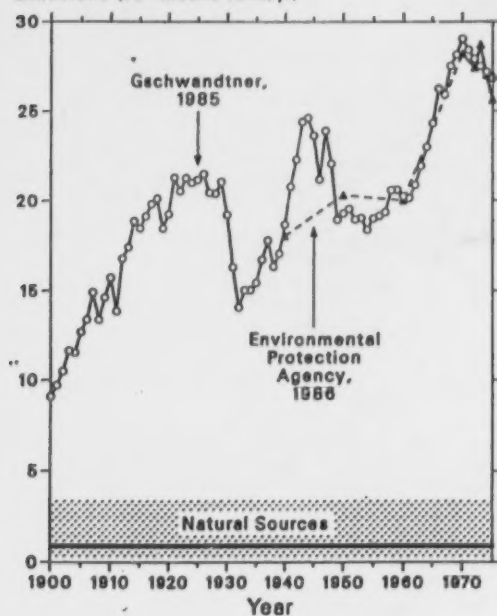
TABLE 4
Anthropogenic Emissions of SO_x , NO_x , and VOC
1985 to 1987

	1985	1986	1987
(millions of metric tonnes)			
SO_x	21.1	21.1	21.2
NO_x	19.8	19.8	20.0
VOC	21.3	20.9	20.6

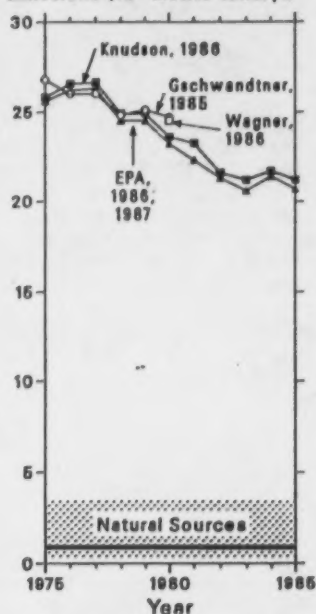
The uncertainties of the estimates are: SO_x , 12 percent; NO_x , 24 percent; and VOC, 50 percent or more (NAPAP, 1987, p. 1-7)

FIGURE 2
Detailed Estimates of Sulfur Dioxide Emissions 1900 - 1985
Compared to Natural Source Emissions

A. Long-range Trends: 1900-1975
Emissions (10^6 metric tons/yr)



B. Recent Trends: 1975-1985
Emissions (10^6 metric tons/yr)



8.2 Tall Stacks

Comments:

Canadian reviewers state that "the contribution of the U.S. SO₂ emissions to the long-range transport problem has been increasing over the last three decades due to the increased use of tall stacks. As a result, the sulphate deposition in sensitive areas of Canada has certainly not been constant since the 1920's." (RMCC, 1987, p. 3). The critique further states: "nowhere in the document are the consequences of the tall stacks and the change in emission patterns discussed in terms of cumulative effects." (RMCC, 1987, p. 6).

Analysis:

During the 1960's, tall stacks were introduced in the United States and Canada to reduce concentrations of SO₂ at ground level near individual major sources. Tall stacks increase the long-range transport of air pollutants. The Executive Summary notes (NAPAP, 1987, p. I-10) that the geographic distribution and concentration of acidic deposition have changed due to the increased use of tall stacks, shifts in the location of sources, and an increase in emissions of anthropogenic oxidant precursors since 1940. The Interim Assessment (NAPAP, 1987, p. 4-60) suggests that tall stacks have increased atmospheric residence times, reduced nearby dry deposition, and increased the distance of sulfate and nitrate transport. Tall stacks are regarded as significant contributors to long-distance transport, but regulations promulgated under the 1977 Clean Air Act amendments have eliminated the incentive to construct stacks exceeding Good Engineering Practice (GEP) height.

The Interim Assessment discusses historical changes in SO₂ emissions and presents limited information on how the distribution of emissions by stack height has changed (NAPAP, 1987, Sections I.3.2.6 and 1.4.1.1). In the Interim Assessment NAPAP made no attempt to estimate how historical emission changes may have affected historical deposition levels in Canada. Also, the Interim Assessment makes no assertion about the trends of sulfate deposition in sensitive areas of Canada. These steps were not taken because of the limitations in the historical emissions data bases, and in the limitations of regional atmospheric deposition models.

8.3 SO₂ Emissions Scenarios: The Base Case Defined and Illustrative Scenarios

Comments:

A number of critics took issue with the assumptions underlying the emissions projections in the Interim Assessment. The Canadian critique states that the forecast of future emissions is misleading and that the Executive Summary suggests that utility emissions will decrease by 55 to 80 percent

(McMillan, 1988, p. 2). The critique questioned the basis for two of the emissions scenario factors discussed in the Interim Assessment: the rate of penetration of new technologies, and the retirement age of existing power plants. The critique states that the emissions estimate "assumes the full implementation of advanced techniques on all new and replacement power plants coming online after 1995" (McMillan, 1988, p. 2) and that "U.S. emissions are much more likely to increase in the next 15 to 20 years as U.S. utilities both increase the use of existing power plants which are essentially uncontrolled, and extend their life expectancy through refurbishing." (RMCC, 1987, p. 3).

The Canadian critique also raised the issue of the sensitivity of future SO_2 emissions to assumptions about the level of nuclear power generation. "The Summary also fails to note that the emission forecast is based on a 300 percent increase in nuclear power generation over 1985 levels. From what Canadian officials understand about the nuclear power industry in the United States, that assumption can only be described as wishful thinking." (McMillan, 1988, p. 2).

Representative Sikorski (1988) argues that the "implication of NAPAP's presentation is that the acid rain problem will disappear on its own." He questioned assumptions about plant retirement age, and growth in nuclear generating capacity. The NRDC (1987) raised similar questions and concluded that, NAPAP chose to "emphasize projections that grossly underestimate future emissions". NRDC also presented a "prudent" SO_2 emissions scenario which shows projections steadily increasing through 2030. During Congressional hearings (U.S. Congress, 1988) Congressman Scheuer also questioned assumptions about power plant retirement age, while Congressman Smith questioned assumptions about the future use of nuclear energy.

Analysis:

NAPAP has not made a forecast or a projection of future emissions which it believes to be the most likely future case. The projections in the Executive Summary are clearly labeled "sensitivity runs" or "scenarios". However, the absence of a definition of the Base Case in the Executive Summary (which was provided in the emissions chapter) may have given the impression that NAPAP had endorsed a specific projection.

The emissions projections in the Interim Assessment are intended to demonstrate the capability of models which can be used to make predictions about future emissions, given a range of assumptions which policymakers might choose to examine. Neither the Executive Summary nor Chapter 1, "Emissions of Acidic Deposition Precursors", suggests that any emissions scenario is more likely than another. The projections in the chapter and in the Executive Summary are sensitivity runs designed for two purposes: one, to examine output of different models given similar assumptions; and two, to illustrate the effect of dominant policy-sensitive assumptions. To conduct sensitivity analyses, a base case must be chosen as a basis for comparison. However, this does not mean that the base case is the most likely case, nor that the range of assumptions used in the sensitivity analysis encompasses the likely future range.

Excerpts from the Interim Assessment underscore NAPAP's view of the reported emissions projections. Section 3.3, "Review of Emission Projections", is introduced with the following text:

"The purpose of this section is to review emission projections that have been made for the critical pollutants and sectors - utility emissions of sulfur dioxide and nitrogen oxides and total emissions of sulfur dioxide, nitrogen oxides, and volatile organic compounds - under similar assumptions. The intention is to examine whether or not different models give similar results when using similar assumptions." (NAPAP, 1987, p. 3-6).

The likelihood of the Base Case is also described:

"The Base Case should not be viewed as the most likely case, however, because this involves judgment of the analyst as to which parameter values are most likely." (NAPAP, 1987, p. 3-15).

Thus, NAPAP has not produced a specific emissions projection, but rather models which policymakers can reliably call upon to examine, through sensitivity tests, the range of conditions likely to result in future emissions changes. Given this background, the scenarios in the Executive Summary, in the chapter, and the one proposed by NRDC can be discussed.

Although certain scenarios in the Executive Summary "suggest that utility emissions will decrease by 55 to 80 percent" (McMillan, 1988, p. 2), these are sensitivity runs rather than most likely cases. The first section of the Future Emissions Summary (NAPAP, 1987, p. I-17) discusses the two major groups of projections, one of which implies an emissions decline of about 30 percent, and the other implies a very small decline between 1985 and 2030. The illustration in the Executive Summary (NAPAP, 1987, Fig. I-8, p. I-17) showed only the base case with the larger projected decline.

8.3.1 Illustrative Scenarios: Nuclear Power Generation

The Interim Assessment did not examine the effect of varying levels of nuclear capacity. The base case emissions forecast presented in the Executive Summary uses the official energy and economic forecasts of the U.S. Department of Energy's Fifth National Energy Policy Plan (NEPP-V), which makes predictions to the year 2010. The growth of nuclear power generation was then extrapolated to 2030. NEPP-V does anticipate an increase in the use of nuclear power generation after the turn of the century.

One alternative nuclear scenario would assume that nuclear generation does not increase above the level projected for the year 2000 (i.e., 110 gigawatts). If the capacity shortfall (of 94 gigawatts) is assumed to be

made up by baseload coal-fired generating units regulated under the New Source Performance Standards (NSPS) requirements rather than by increased use of older power plants regulated under the State Implementation Plans (SIPs), then SO_2 emissions would be about 1.5 million metric tons higher in the year 2030 than projected in the base case. This would be an increase of about 8 percent over the 2030 forecast of total SO_2 emissions in the Interim Assessment. Other scenarios could also be analyzed.

8.3.2 Illustrative Scenarios: Power Plant Lifetimes

The base case assumes an average 50-year lifetime, but the sensitivity of the base case forecast to assumed retirement ages of 40 and 60 years is also described (NAPAP, 1987, Fig. 3-9, p. 3-19). With many uncertainties about future life-extension practices, a range of assumptions was used in the Interim Assessment. One assumption in making the emissions forecasts is that expenditures on life extension will stay below the Clean Air Act value which if exceeded, would require older power plants to limit their emissions according to NSPS standards. Higher retirement ages lead to higher emissions, while shorter retirement ages lead to lower emissions as shown in Figure 3-9, and as stated in the Executive Summary (p. I-17). Greater (or lesser) utilization of existing power plants leads to higher (or lower) emissions, as shown in Figure 3-10 (p. 3-20). Utilization rates were not explicitly discussed in the Executive Summary.

8.3.3 Illustrative Scenarios: Market Penetration of New Technologies

The rate of future penetration of advanced pollution control and combustion technologies into the electric utility generating base is uncertain. The penetration of these advanced technologies is evaluated only in sensitivity runs in the Interim Assessment. The model calculations based on use of advanced technology are clearly stated (NAPAP, 1987, p. I-17) to be "sensitivity runs" intended to show the effect on emissions if certain assumptions about technology penetration are made. The Executive Summary shows that greater use of advanced technologies leads to lower emissions, and states that "in making these analyses, no attempt was made to assess the probability of implementation of the technologies." (NAPAP, 1987, p. I-17).

8.4 The NRDC "Prudent" Scenario

Comments:

The NRDC proposed an emissions scenario for SO_2 based on the following assumptions:

- o a 50-year retirement age for coal-fired utility plants coming on line prior to 1965;
- o a retirement age of greater than 65 years for coal-fired utility plants coming on line after 1965;

- o no new orders for nuclear power with retirement after 40 years for existing nuclear power plants.

The result of using these assumptions in a scenario for future sulfur emissions is to conclude that SO_2 emissions will continue to increase steadily for the next 50 years.

Analysis:

While NAPAP cannot replicate NRDC's calculations, the assumptions stated would all tend to increase SO_2 emissions as compared to the range of scenarios described by NAPAP.

Future Consideration by NAPAP:

The 1990 Integrated Assessment will fully describe the historical patterns of emissions. The 1990 Assessment will report future emissions scenarios for a broad range of assumptions. These scenarios will be based on output from an integrated set of models which reflect changes in energy supply and demand as well as other factors. The methods used to develop the scenarios will be documented in NAPAP's State of Science and Technology Reports to be published in 1990. Absolute and relative certainties of the projections will also be discussed.

The Assessment Plan will outline the process by which major assumptions and ranges of values to be examined for their impact on future emissions will be openly developed. Some of the emissions model outputs will be used to provide input data for regional acidic deposition model calculations. The output of atmospheric models will include deposition fields in the eastern United States and eastern Canada to allow several additional analyses to be addressed in the 1990 Integrated Assessment.

9. SOURCE-RECEPTOR MODELS AND LINEARITY

9.1 Linearity and The 1983 Analysis by the U.S. National Research Council

Comments:

The Canadian critique suggests that the relationship between changes in emissions and changes in deposition is proportional over large areas. (RMCC, 1987, pp. 3,4,15). In support of this view, they note that the U.S. National Research Council (NRC) "found that on the basis of data available to them (as of 1983), there was no evidence for a strong non-linearity between long-term average emissions and deposition [in eastern North America]." (RMCC, 1987, p. 4). Canadian reviewers are concerned about the absence of any mention of the NRC report in the Interim Assessment. The Canadian reviewers also question why NAPAP did not note "that dry deposition, which can account for 20 to 50 percent (or more) of the total, is a linear process." (RMCC, 1987, p. 4).

Analysis:

The Interim Assessment focused on the processes that transport,

transform, and deposit acidic or acidifying compounds. It also briefly evaluated shortcomings in existing models and described the approach to more detailed modeling. The Executive Summary (p. I-20) and the Atmospheric Processes chapter (pp. 4-30 to 32) note the likelihood of nonlinear aqueous-phase oxidation of sulfur dioxide. However, evaluation of the nonlinearities awaits the development and use of tools such as the Regional Atmospheric Deposition Model (RADM), which incorporates nonlinear mechanisms.

In a linear source-receptor relationship, a 50 percent change in emissions from any specific emissions source would be reflected in a 50 percent change in deposition at a receptor, attributable to that source. The linearity of a system reflects a chain of processes: emissions patterns, plume rise in the atmosphere, transport, chemical transformation, scavenging and deposition. Although source-receptor nonlinearity is usually discussed as a result of oxidant limitations in aqueous-phase oxidation of sulfur dioxide, other links in the chain can also contribute to nonlinearity. For example, even if emissions of sulfur stay constant, changes in emissions of nitrogen oxides could lead to changes in sulfur deposition patterns.

Another good example of the possible importance of nonlinear processes is provided by the concern over emissions from tall stacks. It is frequently noted (e.g. RMOC, 1988, p. 3), that an equivalent level of emissions can lead to greater deposition over a large region if the emissions arise from tall stacks. Thus, the NRC statement about linearity must be viewed in context: there are several nonlinear mechanisms that can be important in determining the deposition patterns resulting from a fixed quantity of emissions. A final aspect of linearity also needs to be defined. A change in the geographic distribution of emissions will change the distribution of deposition, independent of the existence of linearity in other parts of the system. Consequently, a change in deposition on a particular sensitive area will depend in large part on the locations of the sources which change their emissions.

The analyses conducted to date provide a scientific foundation, sufficient to concern policy analysts, that nonlinearity exists. The current body of information cannot by itself characterize nonlinearity, but is important in providing chemical and physical realism in models which can. NAPAP believes that the best way to characterize the source-receptor relationship is to construct a scientifically based computer model (i.e., RADM) which allows for, but does not presume, nonlinear operation, and then to use the model to search for nonlinearities that may exist in the system. Model sensitivity analyses which are published or in press demonstrate the utility of models in examining the nonlinearity issue (e.g., Venkatram and Karamchandani, 1986, and Easter and Luecken, in press).

Characterization of the time and space scales of any significant nonlinearity is important in the formulation of policy. A more realistic source-receptor understanding benefits policy formulation by including the ability to design more cost-effective and efficient control strategies.

The Canadian critique is correct in stating that the Interim Assessment did not mention the statements on nonlinearity made by the U.S. National Research Council (NRC). The NRC report (U.S. NRC, 1983) stated:

"The continuous historical record of reasonably reliable data in North America, at Hubbard Brook, indicates no evidence for a strongly nonlinear relationship between annual depositions and annual emissions in the North east. Indirect evidence based on patterns of the ratio of SO_4^{4-} to NO_3^- in annual deposition do not support the hypothesis of a strongly nonlinear relationship between SO_2 emissions and sulfate deposition in eastern North America."

"On the basis of currently available empirical data and within the limits of uncertainty associated with the data and with estimating emissions, we therefore conclude that there is no evidence for a strong nonlinearity in the relationships between long-term average emissions and depositions in eastern North America."

The NRC report was highly controversial. One set of papers evaluating the conclusions, "the Manowitz Review", as well as a preliminary response to that critique, is contained in a Congressional Hearing Report (U.S. Congress, 1983). A critical review of the issue was also published by Hidy (1984). These papers and the NRC report collectively lay out the arguments for and against linearity but provided no resolution of the issue. The application of models capable of expressing nonlinear results such as RADM or the joint Canadian-West German Acid Deposition and Oxidant Model (ADOM) will help test the scientific hypothesis.

Dry deposition can account for 20 to 50 percent or more of the total deposition of sulfur, as asserted by the Canadian reviewers and as noted in the Interim Assessment (pp. 4-55 to 4-59, especially Figs. 4-32 and 4-33; pp. 5-103 to 5-104). The rate of dry deposition is not linearly related to the factors (such as air turbulence and resistance of leaves to uptake of gases) that cause it, although it is linearly related to the concentration of the gases in the atmosphere. Thus, in the context of source-receptor relationships as discussed earlier in this section, dry deposition is presumed to be a linear process.

9.2 The Performance of Existing Models

Comments:

The Canadian critique notes that the omission of any discussion of the current model evaluation (presumably the International Sulfur Deposition Model Evaluation [ISDME] effort) is a serious shortcoming in the Executive Summary. The Canadian critique also states that "the assessment downplays

the good performance of existing models with long-term data evaluations. Their good agreement with independent analyses of air quality data is not mentioned at all." (RMCC, 1987, p. 14).

Congressman Scheuer (U.S. Congress, 1988, pp. 63,64) also questioned "the artfully crafted executive summary" for "excluding data linking emissions from midwest power plants to acid rain in the Northeast of the United States, all up and down the Atlantic Coast, and Canada."

Analysis:

The Canadian reviewers are correct in noting that the Interim Assessment did not include a discussion of the ISDM results. The ISDM report (U.S. EPA and Environment Canada, 1987) examined the ability of eleven linear chemistry atmospheric models "to replicate the spatial patterns of seasonal, as well as annual, amounts of sulfur wet deposition within the uncertainties of the data." The report found that:

"The seasonal predictions of five of the eleven models were within the uncertainty limits of the observed seasonal patterns."

"The seasonal predictions of all but three models were within the same uncertainty limits for at least three seasons."

"The annual predictions of all but three models were within the uncertainty limits of the observed annual pattern."

However, the data base did not allow comparisons for air quality data.

A considerable amount of information has been published regarding the application of linear models to develop source-receptor relationships. The Interim Assessment did not attempt to summarize this literature; rather, it describes NAPAP's view of the utility of the existing models in Section 4.6.3 and 4.6.4.

For statistical models NAPAP concluded that:

"...the confidence with which a statistical model can be applied in a specific circumstance or used to extend from one situation to another (i.e., prediction of future deposition changes due to changed emissions) is low. The accuracy of these models in predicting pollutant concentration and deposition patterns under different various emission scenarios is not known." (NAPAP, 1987, p. 4-66).

For Lagrangian models the Interim Assessment noted that:

"...calculations for each plume are made separately, so

that the treatment of the effect of any interactions between plumes is not accounted for. This requires an assumption of first-order linear chemical processes. There are some exceptions... but their modifications... require limitations in other aspects primarily related to mixing processes." (NAPAP, 1987, p. 4-66).

Thus, although the existing models do not perform poorly under current conditions (based on the ISDM analysis), they do have shortcomings which limit their utility, especially where the combination of pollutant concentrations in the atmosphere may be significantly different from the combinations embodied by current model parameters. Furthermore, available data do not allow these shortcomings to be rigorously examined. NAPAP does believe that the available linear models have value when used to address certain types of questions. The nonlinear models, such as RADIM and ADOM, are valuable because they may help to define the boundaries within which linear models are appropriate. The relative roles of these models are discussed in the following section on "Future Consideration by NAPAP".

The Canadian critique also suggests that independent methods reported at a 1987 meeting of APCA provide answers which converge on those of existing models, thus bolstering confidence in the use of existing models. The three independent papers (we assume them to be Dittenhoefer and Solinski, 1987; Husain et al., 1987; and Rahn et al., 1987) are all based on elemental tracers. Tracer studies have provoked considerable controversy, and their convergence with the results of other model types in some situations should not eliminate challenges to the use of existing linear models. A significant question is the prediction of how changes in emissions would be reflected in changes in deposition at specific receptors. The results of the elemental tracer studies as well as the ISDM study are silent with respect to this question.

In another example provided to illustrate the adequacy of existing models, the Canadian critique states that total sulfur dioxide emissions from sources within 1500 km of southern Nova Scotia⁷ decreased by about 25 percent from the period 1971 to 1983. Over the same period watershed exports of sulfate decreased by 47 percent. We believe that this result is correct and endorsed it in the report to the Bilateral Advisory and Consultative Group (BACG) (see RMCC and NAPAP, 1987). However, we are unaware of computer model analyses which have sought to replicate this result. Further, we believe that this data set, as many other extant sets, provides a very weak test of the quality of model predictions. Finally, the fact that a 25 percent reduction in emissions has led to a 47 percent reduction in deposition seems to suggest the complexity of the source-receptor relationship rather than its simplicity.

⁷ The Canadian critique uses 500 km. However, the report to the BACG (RMCC and NAPAP, 1987, Table 8) cited a similar result but discussed emissions within a 1500 km radius. We believe the critique intended to use the 1500 km radius.

In summary, NAPAP believes that existing models and analyses have value, particularly for describing current patterns, i.e., source-attribution over regions. Their ability to predict how changes in emissions will result in changes in deposition, i.e., source-receptor relations, is open to question as a result of their inability to incorporate major processes thought to be important in controlling source-receptor relationships.

9.3 Trajectory Analysis

Comments:

The Canadian critique notes the omission of "trajectories that show where the air is going" (RMCC, 1987, pp. 4, 14).

Analysis:

The Canadian critique correctly notes that the Executive Summary contains no discussion of atmospheric trajectories. The absence of discussion on this issue in the Executive Summary reflects the absence of a quantitative discussion in the individual chapters of the Interim Assessment. The Atmospheric Processes chapter does contain a qualitative section on transport and dispersion (Section 4.5) which includes a discussion of trajectory analysis methods and uncertainties. Some of the limitations of these methods are discussed in Section 9.2 above.

9.4 The Relative Importance of Chemistry and Meteorology

Comments:

The Canadian critique notes that discussion of several major atmospheric processes was omitted. Specifically, it notes an absence of any discussion on the relative importance of meteorology as compared to chemistry in discussing source-receptor relationships.

Analysis:

The Interim Assessment does not discuss the relative importance of meteorology versus chemistry in source-receptor predictions. The pollutants of interest react during their transport at rates that differ with meteorological conditions. Since different trajectories would have different chemical reaction characteristics, it is difficult and potentially misleading to discuss chemical processes independently of meteorological processes. Interactions between chemistry and trajectories can be addressed by Eulerian models such as RADM.

Estimates of variability due to varying assumptions about chemical mechanisms or to patterns of atmospheric transport were not developed because the available linear models do not reflect the current understanding of atmospheric chemistry. Thus, at this time no relative or quantitative statements can be developed describing the importance of meteorology versus chemistry in source-receptor predictions.

9.5 Source-Receptor Model Use and Evaluation for the 1990 Assessment

Comments:

In several instances the Canadian critique asserts that RADM will not be fully available for use for the 1990 Assessment and that other models should be used as appropriate. It states that "the obsession with the development of an Eulerian model is inexplicable in scientific terms. The whole existing hierarchy of accepted methods of increasing sophistication which are available to estimate source-receptor relationships are not discussed." (RMCC, 1987, p. 4). The critique also states that "the suggestion that the complex models will be 'available in 1989-90 for application in simulating source-receptor relationships', is totally unrealistic." (RMCC, 1987, p. 7).

Analysis:

The Canadian critique is correct in observing that the NAPAP research effort is heavily oriented towards the development and application of an Eulerian model. However, NAPAP will also use other models as appropriate. This point is addressed further in the following section on "Future Consideration by NAPAP".

As a peer review panel (NAPAP, In Press) recently noted, completion of the field evaluation study is not a prerequisite for completion of an applications version of RADM. These activities are being conducted in parallel, and with full cooperation from Canadian researchers. RADM is expected to be used as a tool for policy analysis by the EPA beyond 1990, so that further evaluation utilizing all field study data is planned for this post-NAPAP period. EPA is working closely with other agencies, including those in Canada, in this activity. This evaluation and the application of RADM will allow for the examination of each of the major regional models for each of many possible applications.

Plans to have a documented version of RADM available for use in the 1990 Assessment are proceeding on schedule. A preliminary evaluation of the RADM using six months of field study data is planned for completion in time to be reflected in the 1990 Assessment. By this time, an aggregation methodology will also be in place to allow for longer-term deposition estimates to be prepared based on RADM episodic projections. Activities in 1989 will focus on model applications, sensitivity analyses, and uncertainty analysis. These applications will include use of an Engineering Model, developed from the full RADM, to predict deposition levels for future sulfur emission reduction scenarios, and to determine source attribution.

Future Consideration by NAPAP:

We agree with the Canadian critique that acidic deposition models form

a hierarchy which can be used to investigate numerous questions including trajectory analysis, the impacts of tall stacks on deposition, the relative roles of chemistry and meteorology, linearity, and other questions raised by the Canadian critique. Therefore, NAPAP is developing the 1990 Assessment with the recognition that various models have different roles, rather than one model being "right" while others are "wrong". NAPAP intends to recognize, and use appropriately, the full spectrum of model types. RADM and ADOM represent our best means to produce scientifically defensible estimates of changes in deposition and atmospheric concentrations due to large changes in emissions. The 1990 Assessment Plan will outline the questions to be answered and the plans for use of various atmospheric model types.

Statistical and linear chemistry models are highly parameterized, i.e., built on existing observations related to the contributing processes. These models are best suited to: (1) interpolate data, and (2) estimate concentration and deposition changes due to emissions changes that are small enough not to change the chemical composition of the atmosphere enough to invalidate the use of these models. The nonlinear models can be used to bound the domain of application of linear models for use in predicting future deposition patterns.

An intercomparison of models as though they were all equal is inappropriate, because the models are part of a spectrum, each with a different role. Linear models might appear to perform "better" than more complex models (such as RADM) particularly for simulating current conditions, due to: (1) the high degree of parameterization based on observations which embody current atmospheric chemical combinations and (2) the smoothing of short-term perturbations (longer averaging times are generally involved). For future projections involving major changes in emissions patterns, NAPAP plans to use the best available models (i.e., RADM and ADOM).

Research plans currently in place provide for two major categories of additional information between now and 1990. The first is a synthesis report on linearity that will be produced in the fall of 1989. The second is the model evaluation program, which will provide a data base that is far more complete than any previous data base. While the full model evaluation will not be complete in time for the 1990 Assessment, preliminary results will provide a preliminary quantitative basis for determining the quality of predictions from any regional atmospheric model.

10. DEPOSITION AND AIR QUALITY

Comments:

Descriptions of the pattern of wet precipitation are "misleading and inaccurate" (in Fig. I-1, NAPAP, 1987) or show unbelievably high values (of pH) (in Fig. I-11, NAPAP, 1987). Specifically, "'Pure water' is rarely at pH 7; questionably high pH values for average annual rain, cloud water, and fog water are given", and the map of wet precipitation pH shows higher values than actual station data (particularly for Hubbard Brook) and higher values than other maps (specifically the NADP map, 1987a) from data of the same year (Likens, 1987).

Analysis:

Inspection of the data shows the reasonable characterization of pHs in Figure I-1 on page I-2, not one that is "misleading and inaccurate". However, greater expression of variability or use of ranges in addition to central estimates in the Executive Summary might have precluded Dr. Likens' concerns.

Water without other constituents, i.e. pure water, at sea level pressure and at 25°C has a pH of 7. This pH represents the technical dividing line between solutions which are acidic and those which are basic. The pH of 7 therefore is a useful reference point.

Inspection of the National Atmospheric Deposition Program (NADP) data noted by Dr. Likens for 1985 or that for 1986 (NADP, 1987a) or that in the Interim Assessment on page I-24 supports the notion that the average annual pH of wet deposition is over 5.1 in most of the areas west of the Mississippi and is roughly 4.5 east of the Mississippi, although in both regions individual measurements are higher and lower. (The lowest median pH observed in the eastern United States over the period 1979-1984 was 4.17 at Kane Experimental Forest in Pennsylvania, while the highest was 5.19 at Marcell Experimental Forest in Minnesota). This conclusion is accurately portrayed in the diagram questioned by Dr. Likens.

The pH of summer precipitation for three stations in western Pennsylvania, eastern Ohio, and southwestern New York is given in Table 5. These three stations are the central stations in the region.

TABLE 5
SUMMER WET DEPOSITION PH AT THREE NADP/NIN STATIONS:
1985 and 1986

Station	Summer wet deposition pH	
	1986	1985
Kane Experimental Forest, PA	3.99	*
Chautauqua, NY	4.13	4.12
Wooster, OH	4.21	4.07

Source: NADP(1987a) NADP(1987b)

The data are precipitation weighted means.

* The NADP completeness criteria were not met for this station at this season.

These data from 1985 and 1986 NADP annual reports (NADP, 1987a,b) are consistent with the depiction of average summer rain in western Pennsylvania, eastern Ohio, and southwestern New York in the low 4s as shown on the figure questioned by Dr. Likens. Again, the data are consistent with the figure.

Examples of the pH of cloud water are given in Table 5-14 (NAPAP, p. 5-93). Individual observations ranged from below 2.6 to above 5.8. The 1986 average annual pH of mountain clouds in New York, Virginia and North Carolina was 3.7, 3.5, and 3.4 respectively. Characterizing the pH of average mountain cloud data in these States as about 3.6 (as shown in Figure I-1) is therefore consistent with observations.

Examples of the pH of fog water in California are given in Table 5-13 (page 5-92) of Volume III. The values range from 2.16 to 7.23. (The high pH observations were observed inland). Characterizing the pH of some fogs in the Los Angeles Basin as being in the range of 2.1 to 3.3 (Figure I-1) is therefore entirely consistent with the observations. In summary, Figure I-1 is completely supported by the data rather than at variance with it.

Figure I-11 (NAPAP, 1987) places Hubbard Brook as well as all of New Hampshire on the low side of the 4.4 isopleth, consistent with Dr. Likens' report that the average annual pH has never reached 4.40 at Hubbard Brook. Thus the NAPAP figure is correct with respect to the concern about Hubbard Brook.

The map of annual precipitation weighted pH on page i-24 of the Executive Summary does not show "unbelievably high values for the northeastern United States during 1985." The Interim Assessment and NADP used slightly different procedures to develop isopleth maps which resulted in slightly different isopleth positions. The Assessment isopleths are drawn by computer using a weighing scheme which includes interpolation among the closest twelve stations. The data analyzed include not only NADP data, but also other high-quality U.S. data, as well as high-quality Canadian data. All of these data are required to pass stringent quality checks before their use in developing isopleths. The isopleths produced by NADP are also drawn by computer routines using a different interpolation technique among the closest eight stations. The NADP isopleths are based only on NADP data.

In summary, the portrayal of deposition in the Interim Assessment is consistent with the data.

Uncertainty:

The NADP/NIN wet precipitation network is a high-quality monitoring system which has a considerable investment in quality control, quality assurance and network intercomparison. There is uncertainty in the data as a result of the sampling and analytical methods. (See for example, reports on precision and bias in NAPAP, 1987, p.5-38, See et al., 1988, and Brooks et al., 1987). Cloud and fog water data are more limited and are developed from

individual research projects which often have the dual purpose of methods development as well as monitoring. "The paucity of measurements of cloud and fog liquid water content and the uncertainty associated with current methods for measuring liquid water content...impede the interpretation and estimates of chemical inputs to natural ecosystems from the deposition of fog or cloud water." (NAPAP, 1987, p. 5-89). The values and ranges reported in the Interim Assessment (pp. 5-92 and 5-93) represent a reasonable portrayal of those data.

Uncertainties in the isopleth patterns shown in the Interim Assessment are described (NAPAP, 1987, p. 5-63 to 5-70): "for most of the eastern United States the true value [of annual wet sulfate deposition] is estimated to be within ± 25 percent of the interpolated value; the median fractional interpolation error over this area is only ± 15 percent." These uncertainty estimates include not only the uncertainty associated with the interpolation methodology, but also the uncertainty associated with the individual station data.

Future Consideration by NAPAP:

NAPAP will continue to support the collection of wet deposition data as well as mountain cloud data. NAPAP has also initiated a rural air quality monitoring network which was just beginning to operate at the time of the Interim Assessment. The 1990 Assessment will describe deposition technology, data bases, and analytical methods which will provide a basis for the exposition of patterns of deposition and its associated uncertainties.

ECONOMICS

11. ECONOMICS

11.1 Absence of Economic Analyses

Comment:

Congressman Scheuer expressed concern over "failing to quantify economic costs of acid rain damage." (U.S. Congress, 1988, p. 64)

Analysis:

Congressman Scheuer is correct in his view that the Interim Assessment conducted only very limited economic analyses. Recreational fisheries in the Adirondacks which had probably been damaged by acidic deposition were valued by recreational fishermen (using a travel cost method) at somewhere between \$1 million and \$13 million per year. (NAPAP, 1987, p. 8-69 ff). Gain in crop value attributable to a 25 percent decrease in ozone exposure was estimated to be on the order of \$1 billion to \$2 billion per year. (NAPAP, 1987, p. 6-41). A possible financial benefit to crops from the fertilizing effect of nitrogen deposition was calculated at \$200 million per year (NAPAP, 1987, p. 6-42). The cost of liming surface waters and crop land was also provided (NAPAP, 1987, p. 8-69 and 6-43).

11.2 Crop Loss Estimates

Comment:

Dr. Likens suggests that the rough economic calculations on crop loss due to ozone are erroneous. He suggests that if a 20% decrease in ozone concentration could result in crop benefits on the order of a billion dollars, then the total loss from ozone damage on crops should be valued at \$5 billion.

Analysis:

Executive Summary statements regarding dollar values relating to ozone damage to agricultural crops were purposefully not specific because of the uncertainty regarding natural background ozone levels (they are estimated to range between 10 and 40 ppb as a 7-hr daily average) as well as uncertainties in the economic models and dose-response functions. Calculations of economic loss from ozone should not be based on comparisons of existing crop yields to those which might be achieved with no ozone. Ozone-free conditions in the ambient environment are unachievable, and most dose response experiments have been conducted at ozone levels greater than 25 ppb. Also, the ozone dose-yield response relationships developed for most crops are non-linear and the slope of the response functions decrease as ozone concentrations decrease to background levels. (See for example, Figs. 6-17 and 6-18, NAPAP, 1987, pp. 6-32 and 6-33). Thus, the benefit from a 40 percent reduction in ozone will be less than double the benefits of a 20 percent reduction. The shape of the response function is also less certain when plants are subjected to other stresses.

In addition to the above uncertainties regarding background ozone and the crop dose-response functions, there are also uncertainties associated with the economic models used in calculating benefits from ozone reductions. Several different economic models have been used, and these give a range in calculated benefits. For these reasons, the terminology used in the Executive Summary was chosen to reflect the uncertainty of the estimates. The phrase "on the order of a billion dollars" was selected to indicate a possible range of dollars for each of the several economic analyses.

Uncertainty:

The dose-response experiments underlying the economic analysis of the effect of ozone on crops as reported in the Interim Assessment included 43 highly replicated field studies of six major crops which account for over 75 percent of U.S. cropland acreage. A new crop loss assessment will be published later this year by EPA, and will include two more major crops which increases the scope to about 90 percent of U.S. cropland acreage. The economic model and ozone exposure data were also updated for the new assessment. The new analysis predicts benefits within the same range as those predicted by the 1984 assessment: a 25 percent decrease in ozone is expected to result in benefits of one to two billion dollars. The new analysis also indicates that crop losses resulting from ozone

would not be as great during seasons when plants are subjected to severe drought stress compared to years when there is no drought stress.

Future Consideration by NAPAP:

The 1990 Assessment Plan will outline steps to develop a comprehensive analysis of three kinds of values that are associated with acidic deposition: economic values, conservation values, and health values. NAPAP has increased its emphasis on economics and will incorporate results in the 1990 Assessment. Future economic analyses will involve close collaboration with NAPAP's non-economic scientific personnel. However, economic analysis is unavoidably limited by uncertainties in noneconomic technical knowledge and by limitations of available economic models and methods. NAPAP's Assessment Plan and its 1989 update will provide additional information about the economic methodologies to be used.

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ABBREVIATIONS AND ACRONYMS USED

ADOM	-	Acid Deposition and Oxidant Model
ALSC	-	Adirondack Lake Survey Corporation
ANC	-	acid neutralizing capacity
APCA	-	Air Pollution Control Association
BACG	-	Bilateral Advisory and Consultative Group on the Long-Range Transport of Air Pollutants (U.S. and Canada)
CASAC	-	Clean Air Scientific Advisory Committee (U.S. EPA)
DDRP	-	Direct/Delayed Response Project
ELS	-	Eastern Lake Survey
EPRI	-	Electric Power Research Institute
ERP	-	Episodic Response Project
ha	-	hectare
hr	-	hour
ISDME	-	International Sulfur Deposition Model Evaluation
kg	-	kilogram
m	-	meter
m ⁻³	-	per cubic meter
mg	-	milligram
NADP	-	National Acid Deposition Program
NAPAP	-	(U.S.) National Acid Precipitation Assessment Program
NO ₃ ⁻	-	nitrate ion
NO _x	-	oxides of nitrogen
NRC	-	(U.S.) National Research Council
NRDC	-	Natural Resources Defense Council
NSFS	-	New Source Performance Standards
NSS	-	National Streams Survey
NSWS	-	National Surface Water Survey
NTN	-	National Trends Network
OECD	-	Organization for Economic Cooperation and Development
PIRLA	-	Paleolimnologic Investigations of Recent Lake Acidification
RADM	-	Regional Acid Deposition Model
RMCC	-	(Canadian) Federal/Provincial Research and Monitoring Coordinating Committee
SIP	-	State Implementation Plan
SO ₂	-	Sulfur dioxide
SO ₄ ⁻	-	Sulfate ion
μg	-	microgram